IMPERX

Cheetah KAC CMOS CAMERA
User Manual
with **CoaXPress**® Interface

The Cheetah series of CMOS cameras offer the C4080 model and C2880 model with the CoaXPress® (CXP) output standard. The C4080 and C2880 are ruggedized cameras featuring advanced ON Semiconductor KAC sensors, industrial-grade components, superior processing power for producing high-resolution images at fast frame rates, and wide dynamic range. The cameras provide exceptional durability and performance in the most demanding applications.

Document Version 1.1

IMPERX™
Industrial Cameras & Imaging Systems

About Imperx, Inc.

IMPERX, Inc. is a leading designer and manufacturer of high performance, high quality digital cameras, frame grabbers, and accessories for industrial, commercial, military, and aerospace imaging applications including flat panel inspection, biometrics, aerial mapping, surveillance, traffic management, semiconductors and electronics, scientific & medical Imaging, printing, homeland security, space exploration, and other imaging and machine vision applications.

Fortune 100 companies, federal and state government agencies, domestic and foreign defense agencies, academic institutions, and other customers worldwide use IMPERX products.

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Warranty

IMPERX warrants performance of its products and related software to the specifications applicable at the time of sale in accordance with IMPERX's standard warranty, which is 2 (two) years parts and labor. FOR GLASSLESS CAMERAS THE CCD OR CMOS IS NOT COVERED BY THE WARRANTY.

Do not open the housing of the camera. Warranty voids if the housing has been open or tampered.

IMPORTANT NOTICE
This camera has been tested and complies with the limits of Class A digital device, pursuant to part 15 of the FCC rules.

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REVISION HISTORY

Revision	Date	Reviser	Comments
1.0	10/01/2019	R.Johnston	Initial release.
1.1	1/03/2020	I. Barabanova	Removed logos

1 About the Cheetah Camera

1.1 General

The Cheetah Python series of cameras provide an imaging platform with the latest digital technology and industrial grade components. They use CMOS imaging sensors and offer a broad range of resolutions and frame rates. Cheetah cameras are available in both monochrome and color.

The cameras in this manual are compatible with the CoaXPress (CXP) output interface. Use your frame grabber's GeniCam™ compliant capabilities to configure the camera. The following table describes the C4080 and C2880 model cameras covered in this manual.

Model	Resolution	Type	Optics	CMOS	Model
C4080M	4000 x 3000	Mono	4/3"	ON Semiconductor	KAC-12040
C4080C	4000 x 3000	Color	4/3"	ON Semiconductor	KAC-12040
C2880M	2832 x 2128	Mono	1"	ON Semiconductor	KAC-06040
C2880C	2832 x 2128	Color	1"	ON Semiconductor	KAC-06040

Table 1: CHEETAH C4080 and C2880 cameras overview.

Cheetah CMOS cameras are advanced, high-resolution, progressive scan cameras. They are fully programmable and field upgradeable. Programmable functions include exposure control, frame rate control, area of interest, subsampling, pixel averaging, gain, offset, triggering options, strobes, output control, bad pixel correction, and user-programmable look-up tables (LUT). The cameras use ON Semiconductor area scan KAC CMOS image sensors and feature a built-in processing engine, low noise characteristics, and optimized thermal distribution.

The C4080 and C2880 cameras provide both rolling shutter operation and global shutter operation. Rolling shutter operation enables the widest dynamic range. Global shutter operation provides superior motion capture.

The cameras give you the options of controlling frame exposure time internally or with an external pulse width. They support exposure times up to 1 second with 1 microsecond increments in rolling shutter mode and 5 microsecond increments in global shutter mode. You can program a custom Area of Interest (AOI) and implement subsampling or pixel averaging. Pixel averaging is a unique feature producing reduced noise and improved signal-to-noise ratio by blending adjacent pixel information. Analog gain is available up to 12 dB (4x) in 12-bit digitization mode and up to 18 dB (8x) in 10-bit mode. Digital gain controls allow expansion of the low-end signal with 24dB (15.9x) of additional gain available. Wide dynamic range enables multi-integration times within one frame period by compressing bright areas into the available output range and extending the visible dynamic range up to 100db (global shutter mode only) with up to three knee points.

Built-in gamma correction and user-defined look-up tables (LUT) optimize the camera's dynamic range further. Applying defective pixel correction (DPC) and hot pixel correction (HPC) can correct bad pixels that are either over-responding or under-responding. Auto-White Balance (AWB) is available in color cameras to correct for color lighting temperatures.

The CXP cameras have a 2-Channel CXP-6 CoaXPress output interface that includes 8-, 10- and 12-bit data transmission, as well as camera control functionality in one cable.

1.1.1 Key Features

- Global shutter (GS) or rolling shutter (RS)
- Monochrome or color
- Large 4.7-micron pixels
- Excellent near infrared (NIR) sensitivity
- Ultra-low fixed pattern noise
- Exceptional blooming suppression
- Fast frame rates
- Extended Dynamic Range (WDR): 3 knee points, piece-wise Linear
- Color and monochrome pixel averaging (4x and 9x)
- Subsampling up to 32x
- One Area of Interest
- Analog and digital gain controls
- Offset control
- Three selectable trigger sources: external, pulse generator, or software
- Two programmable output strobes
- Auto-white balance: Auto, Manual, or Off
- Image enhancements, horizontal and vertical flip
- Two 12-bit look-up tables, one LUT pre-programmed with gamma 0.45
- Defective pixel correction, hot pixel correction
- Two programmable external inputs and two external outputs
- CoaXPress interface
- Temperature monitor
- Field upgradeable firmware, LUT, DPC, and HPC

1.2 Cheetah Specifications

1.2.1 General Information

A CMOS camera is an electronic device for converting light into an electrical signal. The camera contains a light sensitive element CMOS (Complementary Metal Oxide Semiconductor) where an electronic representation of the image is formed. The CMOS image sensor consists of a two-dimensional array of sensitive elements called silicon photodiodes, also known as pixels. The photons falling on the CMOS surface create photoelectrons within the pixels, where the number of photoelectrons is linearly proportional to the light level. Although the number of electrons collected in each pixel is linearly proportional to the light level and exposure time, the number of electrons varies with the wavelength of the incident light.

1.2.1.1 Global and Rolling Operations

Cheetah C4080 and C2880 cameras support both global and rolling shutter readout modes.

In Global Shutter (GS) mode, every pixel starts and stops integration at the same time. This mode provides superb clean capture of moving scenes without the need for a mechanical shutter. In GS mode, all pixel data is stored in light shielded regions within each pixel and held there until readout (Figure 1).
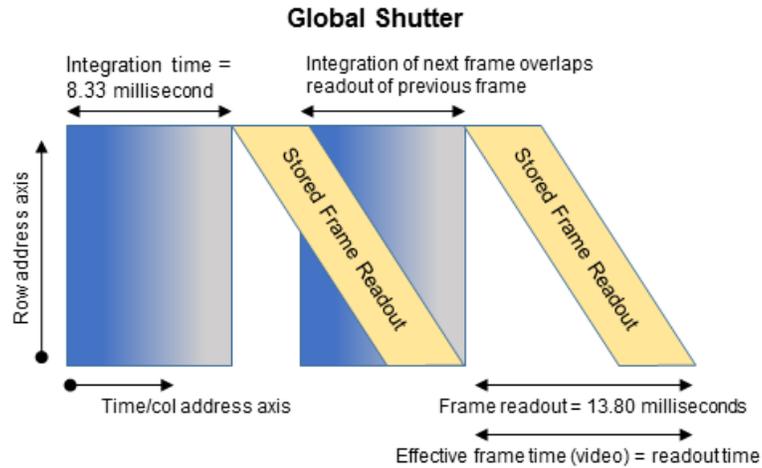
Figure 1: Global Shutter Description.

In Rolling Shutter (RS) mode, each line of the image sensor is captured at a slightly different time. This can cause distortions in the image if an object is moving very quickly and the integration time is short with respect to the frame readout time. In rolling shutter mode, pixels in a row are cleared of charge, allowed to integrate for the required exposure time, and then read out of the entire line. The resetting of each line ripples through the array and each line is exposed with a slight time delay (equal to the line readout time) relative to the previous line. In RS mode, the global shutter transistor in each pixel provides noise reduction.
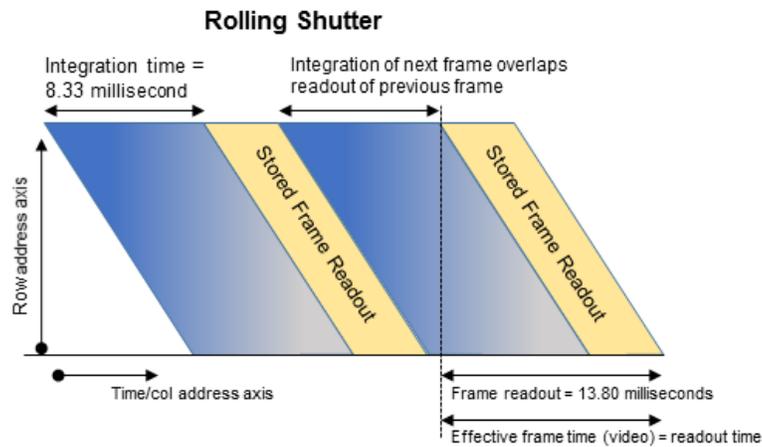
Figure 2: Rolling Shutter Description.

1.2.1.2 A/D architecture and Blooming Suppression

The ON Semiconductor KAC-12040 and KAC-06040 image sensors have an analog-to-digital (A/D) converter on each column and built-in correction circuits that automatically compensate and correct for fixed pattern noise within the image array. With an A/D converter on each column of the imaging array, digitization occurs within each line time rather than within a readout pixel time, which improves noise performance. Two rows are read out simultaneously (one from the top of the array and one from the bottom of the array) and, in this manual, this is referred to as "one line." While the camera has 3000 rows in the active image area, there are only 1500 lines read out and while the C2880 camera has 2128 rows, only 1014 lines are read out. The total number of rows including overhead readout of the C4080 camera is 3136 (1568 lines) and the C2880 camera is 2292 rows (1146 lines) The camera takes care of all the details of re-ordering the lines within frame grabber memory.

The A/D converter architecture allows the user to select between 10 or 12-bit digitization. The Cheetah C4080 supports both 10 and 12-bit digitization. In 12-bit digitization mode, the A/D conversion time is longer than the minimum chip readout time and this reduces maximum frame rates. In 10-bit digitization the A/D conversion time is reduced increasing the maximum frame rate. The image sensor provides up to eight LVDS readout banks and the time to readout one line from the image sensor is less than the time necessary to output the data using CoaXPress. The camera compensates for this mismatch in data output rates by adding additional delay at the end of each line.

Each pixel within the imaging array has extremely robust anti-blooming suppression eliminating classic 'black sun' artifacts present in other CMOS imaging arrays. The CMOS readout architecture also eliminates column smearing often seen in traditional CCD image sensors under extremely bright exposure conditions.

The time interval required for all the pixels, from the entire imager, to be clocked out of the CMOS is called a frame. To generate a color image a set of color filters (Red, Green, and Blue) arranged in a "Bayer" pattern, are placed over the pixels. The starting color is Green. The following illustrations show the CMOS image sensor architecture and the camera's spectral response.
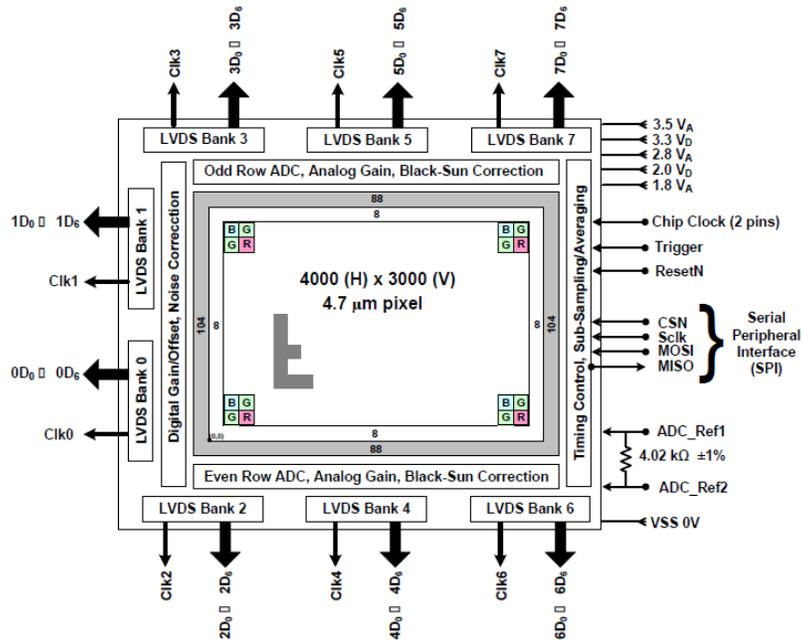
Figure 3: C4080 KAC-12040 CMOS image sensor architecture.
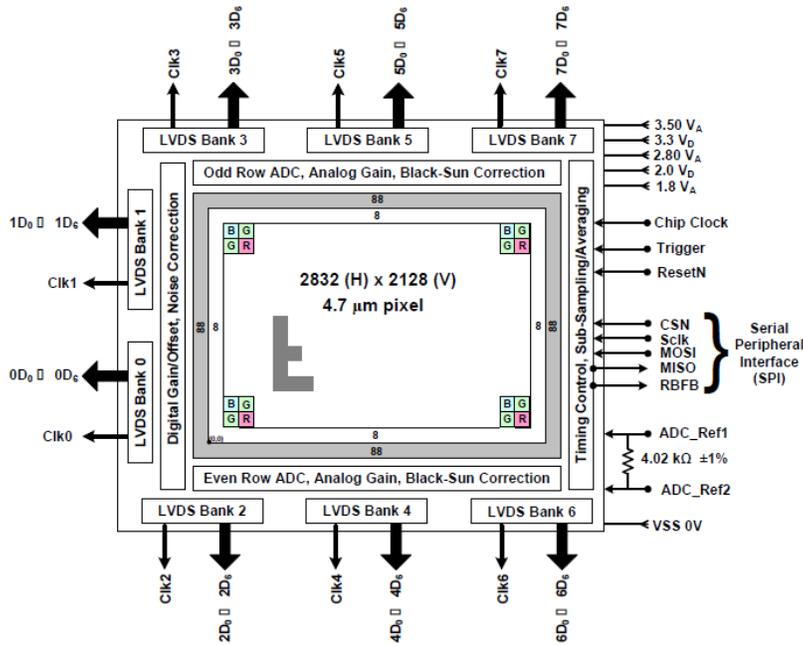
Figure 4: C2880 KAC-06040 CMOS image sensor architecture.

1.2.2 Spectral Sensitivity Curves
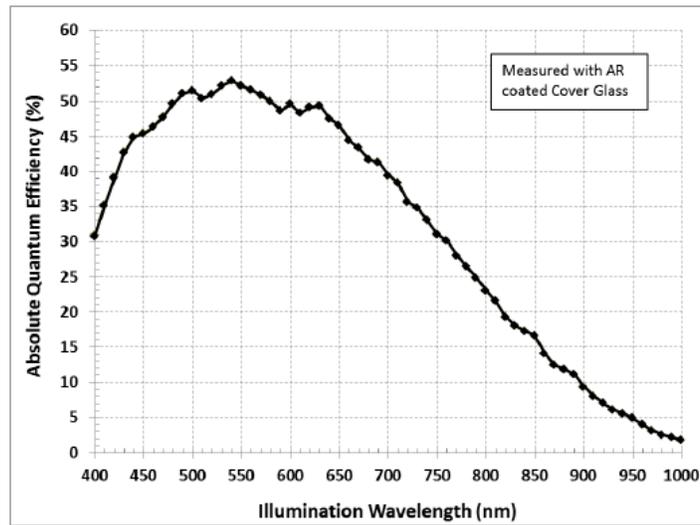
Figure 5: C4080 KAC-12040 CMOS image sensor mono spectral response (monochrome with the cover glass).
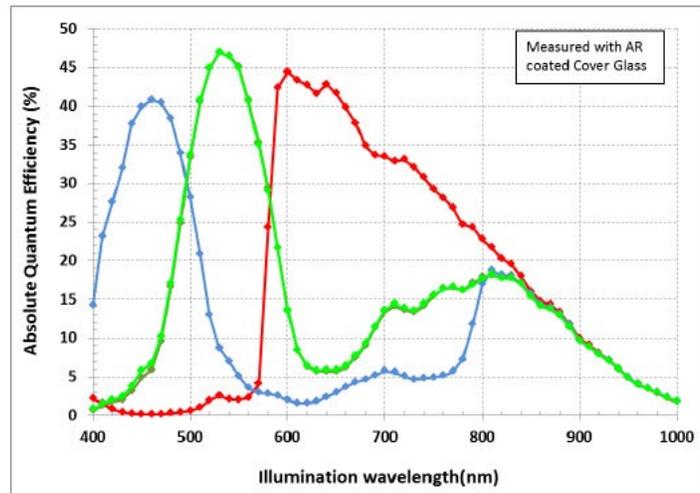
Figure 6: C4080 KAC-12040 CMOS image sensor typical color spectral response (micro-lens with cover glass).
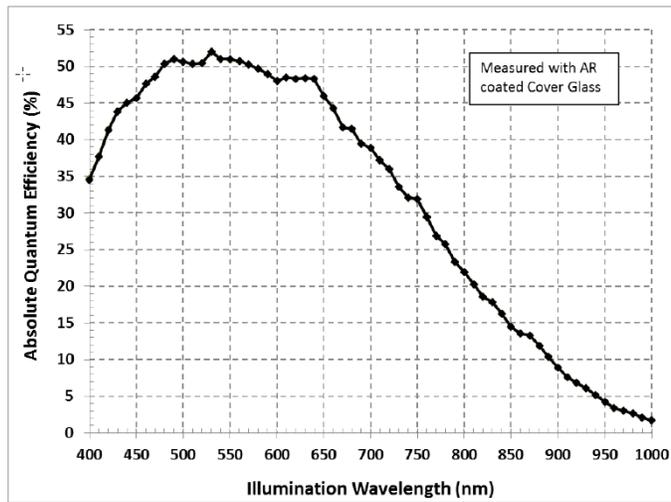
Figure 3: Monochrome QE (with Microlens)

Figure 7: C2880 KAC-06040 CMOS image sensor mono spectral response (monochrome with the cover glass).
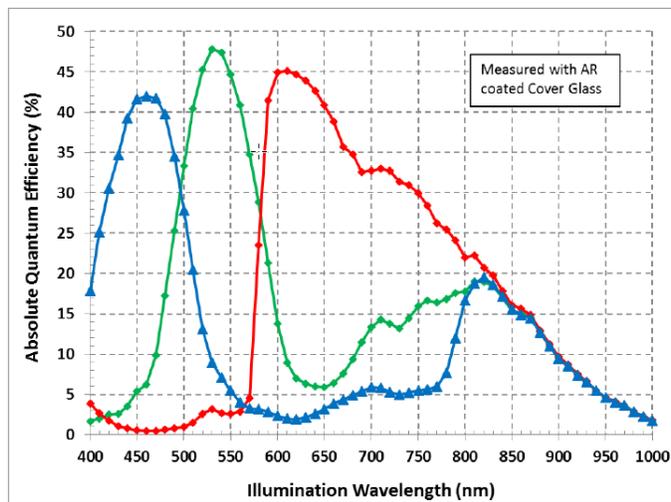
Figure 4: Bayer QE (with Microlens)

Figure 8: C2880 KAC-06040 CMOS image sensor typical color spectral response (micro-lens with cover glass).

1.3 Technical Specifications

The following table describes general features and specifications of Imperx Cheetah KAC cameras.

Specifications	C4080 / C2880
Shutter operation	Global or Rolling
Frame time (long int.)	up to 1 sec
Subsampling	Up to 32x
Pixel averaging (color and mono)	4x, 9x
Wide Dynamic Range	Yes
Auto white balance	Yes
Test image	Static, Dynamic
Mirror image (H Mirror)	Yes
Vertical image (V Mirror)	Yes
Image overlay	Crosshairs at optical center
Defective pixel correction	Static, Dynamic, User DPM
Hot pixel correction	Static, Dynamic, User HPM
Inputs	2 IN (OPTO, LVTTL)
Outputs	2 OUT (OPTO, TTL)
Triggers	Programmable Rising/Falling, De-bounce
Pulse generator	Yes
In-camera image processing	2 LUTs
Camera housing	High grade aluminum
Supply voltage range	5V to 33V DC
Upgradeable firmware	Yes
Upgradeable LUT, DPM	Yes
Environmental - operating	- 40°C to + 85°C
Environmental – storage	- 50°C to + 90°C
Relative humidity	10% to 90% non-condensing

Table 2: Cheetah camera general specifications.

The following table describes specific features and specifications of the Cheetah C4080 and C2880 CoaXPress cameras.

Specifications	C4080	C2880
Active image resolution	4000x3000 (std.); 4016x3016 (max.)	2832x2128 (std.); 2848x2144 (max.)
Active image area (H, V)	18.8mm x 14.1mm, 23.5mm Diagonal	13.1mm x 10.0mm, 16.65mm Diagonal
Pixel size	4.7 µm	4.7 µm
Sensor format	4/3" optical format	1" optical format
Video output	Digital, 8/10/12-bit	Digital, 8/10/12-bit
Output structure	10-tap	10-tap
Data clock	80 MHz	80 MHz
Camera interface	CoaXPress	CoaXPress
Connector	1.0/2.3 DIN	1.0/2.3 DIN
Maximum frame rate	70 fps	160 fps
Dynamic Range, Rolling/Global	72 (RS) / 56 (GS) dB	72 (RS) / 56 (GS) dB
Shutter speed	1 µs to 1sec (RS) 5µs to 1 sec (GS)	1 µs to 1 sec (RS) 5µsto 1 sec (GS)
Area of Interest	One per Frame	One per Frame
Analog gain	0 to 12dB (12-bit), 0 to 18dB (8 & 10-bit)	0 to 12dB (12-bit), 0 to 18dB (8 & 10-bit)
Digital gain	0 to 24dB	0 to 24dB
Black level offset	0 to 2048, 1/step	0 to 2048, 1/step
Dual frame switching Control	Manual, Auto, External Trigger	Manual, Auto, External Trigger
Hardware trigger	Asynchronous	Asynchronous
Strobe modes	Programmable Width, Delay	Programmable Width, Delay
Trigger sources	External, Pulse Generator, Software	External, Pulse Generator, Software
Trigger features	Rising/Falling Edge, De-glitch, Delay, Strobe	Rising/Falling Edge, De-glitch, Delay, Strobe
Size (W x H x L)	72.0 x 72.0 x 33.5 mm	72.0 x 72.0 x 33.5 mm
Weight	384 g	384 g
Lens mount	F-Mount (default), C-Mount	C-Mount (default), F-Mount
Power	450mA	450mA
MTBF	MTBF > 323,000 hours @ 40°C	MTBF > 323,000 hours @ 40°C

Table 3: Cheetah C4080 and C2880 specifications.

1.4 Ordering Information

Cheetah C4080, C2880 Ordering Codes			Sample Code: CXP-C4080M-RF000	
Sensor Manufacturer: ON Semiconductor				
Interface	**Camera Number**	**Sensor Type**	**Lens Mount**	**Filter Option**
CoaXPress	C4080 – 4000 x 3000 C2880 – 2832 x 2128	M – monochrome C - color	F-Mount (Default) C-Mount M-M42 B-Birger	0 - none
				2 – Color w/out filters (C-, F-Mount)
				3 – Color w/front CG filter (C-Mount)
				4 – Mono w/front CG filter (F-Mount)
				5 - Mono with Front IR filter (C-Mount)
				6 - Mono with Front CG filter (C-Mount)
				7 - Mono with Front CG filter (F-Mount)
				8 - Mono with Front IR filter (F-Mount)
				A - Mono with rear CG filter (F-Mount)
				B - Mono with rear IR filter (F-Mount)
				C - Color with rear CG filter F-Mount)
				D - Color with rear IR filter (F-Mount)

NOTE: For custom camera configurations, contact Imperx, Inc.

1.4.1 Technical Support

Imperx tests each camera before shipping. If the camera is not operational after power up, check the following:

1. Check all cables. Make sure that all connectors are firmly attached.
2. Check the status LED and verify that it is steady ON. If it is not, refer to the LED section.
3. Enable test mode and verify that the communication between the output interface and the camera is established. If the test pattern is not present, power off the camera, check all the cabling, CoaXPress settings, and computer status.
4. If you still have problems with the camera operation, contact technical support at:

   Email: techsupport@imperx.com
   Toll Free 1 (866) 849-1662 or (+1) 561-989-0006
   Fax: (+1) 561-989-0045
   Visit our Web Site: www.imperx.com

2 Hardware

2.1 CoaXPress Output

The back panel of the camera provides connectors to the CoaXPress interface and other external equipment. The panel also provides a status LED indicator. The panel includes:

1. Two 75 ohm, 1.0/2.3 DIN mini-coax receptacles (Amphenol P/N 282121-75) providing 2-channel data output, control data, trigger, general purpose I/O connection, and power over CXP.
2. Male 12-pin connector provides the I/O interface.
3. USB type B programming/SPI connector.
4. Status LED indicating the status of the camera (refer to Status LED section).
5. Serial Number showing the camera model and serial number.

12- pin Hirose type connector for I/O interface

Status LED

2-channel CXP-6 using 1.0/2.3 DIN mini-coax connectors for data output, control, and general I/O

Connector for factory use
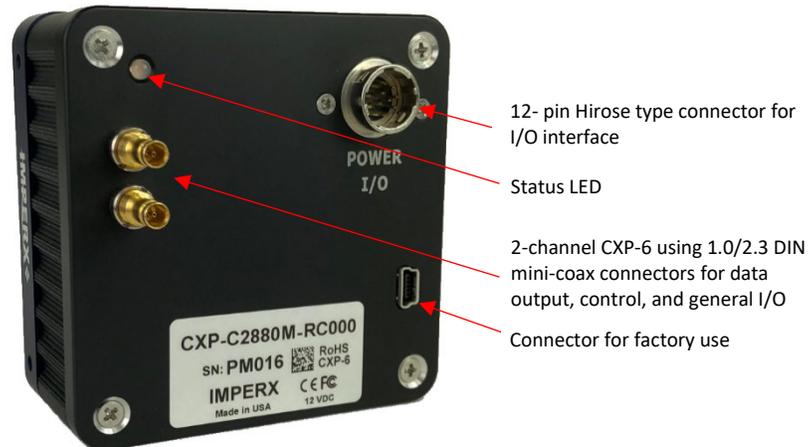
Figure 9: Camera back panel.

2.2 CXP Camera Power and Data Connector

The coaxial cable connected to the camera provides power over CXP (PoCXP). The Camera's video data output, control data, triggering, and general I/O's are serialized and continuously transmitted over CoaXPress (CXP-6) using a standard 75-ohm mini-coaxial cable. Imperx offers mini-coax cables with a 1.0/2.3 DIN mini-coax push/pull plug on one end and a BNC connector on the opposing end. The interface provides a high-speed downlink up to 6.25 Gbps for video transport and a lower speed 20Mbps uplink for communication and control.

NOTE ✳

The CXP output interface requires a frame grabber for collecting and storing the camera's output. The frame grabber installs in the host computer. It enables you to view images and configure the camera.
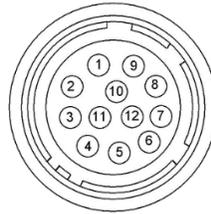
Figure 10: Camera I/O Connector Pin-outs.

2.2.1 I/O Connector Pins

A 12- pin Hirose type connector on the back of the camera provides an I/O interface with the following pin mapping.

| Pin	Signal	Type	Description
1	Reserved	Reserved	
2	Reserved	Reserved	
3	Reserved	–NC	No Connect
4	Reserved	NC	No Connect
5	OUT2 OPTO -	Opto-Switch contact 2	General Purpose Output 2-
6	GP OUT1 RTN	TTL Ground Return	General Purpose Output 1 Return
7	OUT1 TTL Gnd	TTL OUT 1	General Purpose Output 1
8	OUT1 TTL Signal	Opto-isolated IN 1	General Purpose Input 1
9	IN OPTO +	TTL/LVTTL IN 2	General Purpose Input 2
10	IN1 OPTO -	Ground Return IN1	General Purpose Input 1 Return
11	IN2 TTL Gnd	LVTTL Ground Return IN2	General Purpose Input 2 Return
12	OUT2 OPTO	Opto-Switch contact 1	General Purpose Output 2+

Table 4: I/O connector pin mappings.

2.2.1 LED Status Indicators

The camera has LED status indicators located on the back panel. The LED color and light pattern indicate the camera status and mode of operation:

Camera LED Color	Status Description
Green steady ON	Normal operation. You should see a normal image coming out of the camera.
Green blinking	Trigger enabled.
Amber steady ON	Test mode enabled.
Red steady ON	Communications or firmware load error.*
LED OFF	No power. Indicates power supply failure.**

Table 5: Camera LED status indicators.

*Re-power the camera and load the factory settings. If the condition is still present, contact the factory
**Potentially a faulty external AC adapter. To restore the camera operation, re-power the camera and load the factory settings. If the LED is still OFF, contact the factory.

2.3 Mechanical, Optical, Environmental

2.3.1 Mechanical

The camera housing consists of high quality series 6000 aluminum. For maximum usability, the camera has eight (8) M3X0.5mm mounting screws located towards the front and the back. Cameras ship with an additional plate with ¼-20 UNC tripod mount and hardware. All dimensions are in millimeters.

### 2.3.1.1 C4080 CoaXPress Mechanical Drawings
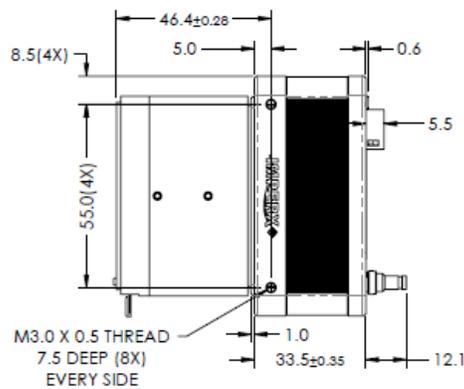

Figure 11: C4080 side view.
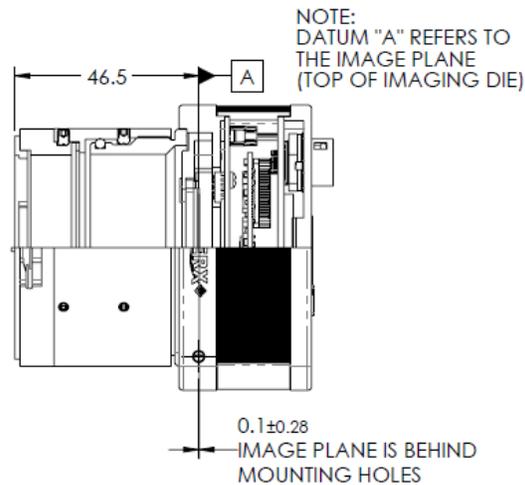
*Figure 12: C4080 side view with image plane.*
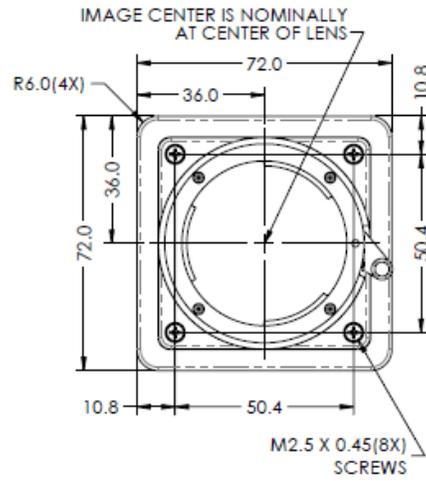
Figure 13: C4080 front view.
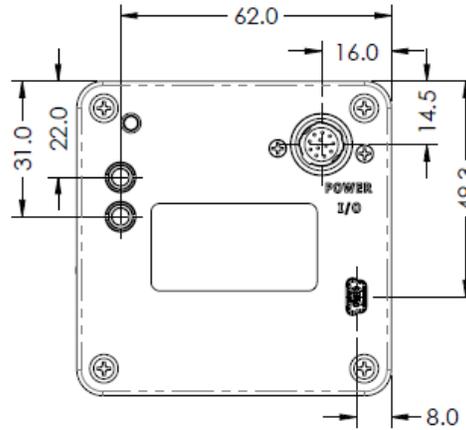
Figure 14: C4080 back panel view.

2.3.1.2 C2880 CoaXPress Mechanical Drawings
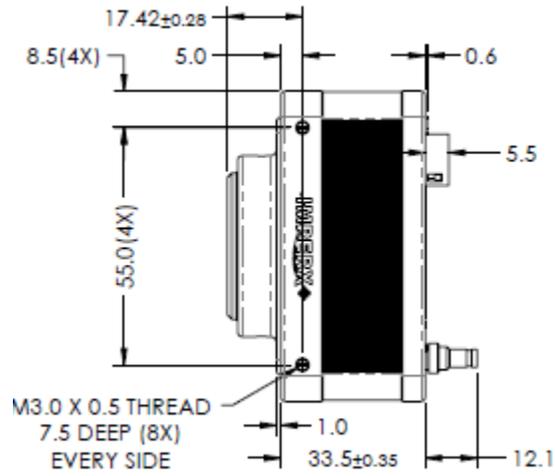

Figure 15: C2880 side view.
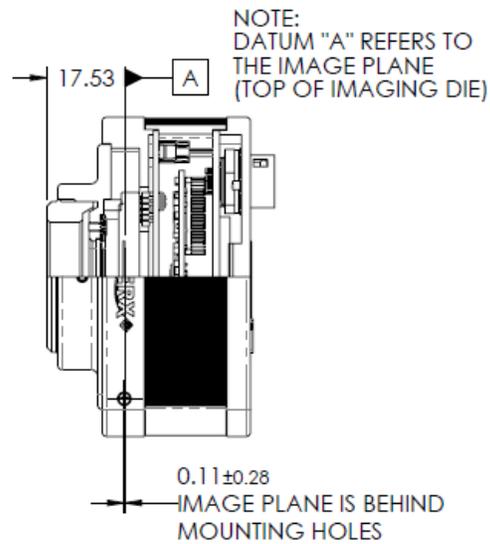
Figure 16: C2880 side view with image plane.
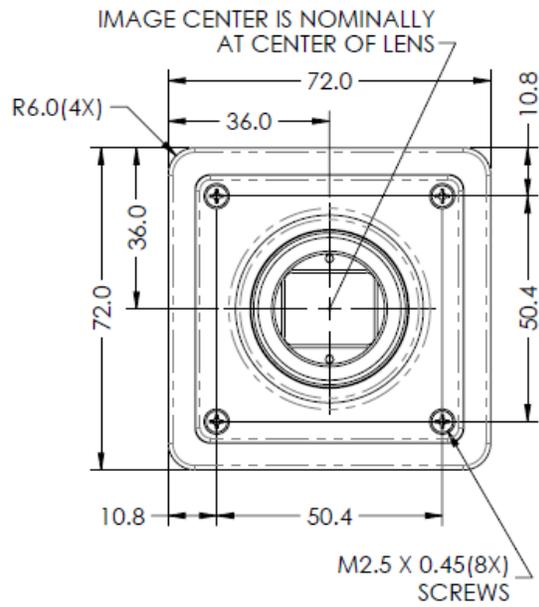
Figure 17: C2880 front view.
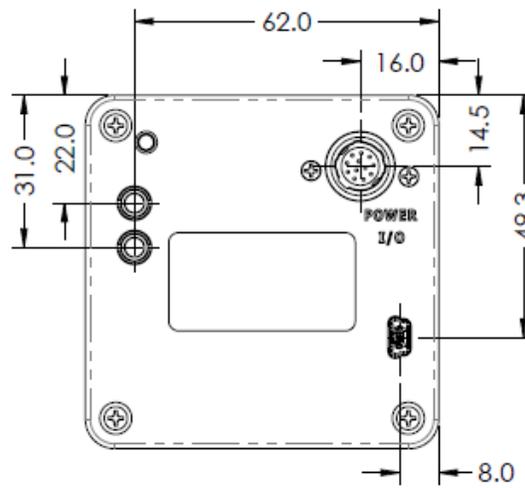
Figure 18: C2880 back panel view.

2.3.2 Optical

The C4080 camera (72 x 72 mm) cross-section comes with an adapter for F-mount lenses, which have a 46.50 mm back focal distance. The C2880 camera (72 x 72 mm) cross-section comes with an adapter for C-Mount lenses, which have a 17.5 mm.

The camera performance and signal-to-noise ratio depend on the illumination (amount of light) reaching the sensor and the exposure time. Always try to balance these two factors. Unnecessarily long exposures will increase the amount of noise and thus decrease the signal-to-noise ratio.

The cameras are highly sensitive in the infrared (IR) spectral region. All color cameras have and IR cut-off filter installed. The monochrome cameras do not include an IR filter. The camera includes space under the front lens bezel for inserting an IR filter (1 mm thickness or less) if necessary.

CAUTION ⚠️

1. Avoid direct exposure to a high intensity light source (such as a laser beam). This may damage the camera optical sensor!
2. Avoid foreign particles on the surface of the imager.

2.3.3 Environmental

The camera operating temperatures range from -40°C to +85°C in a dry environment. The relative humidity should not exceed 80% non-condensing. Always keep the camera as cool as possible. Always allow sufficient time for temperature equalization if the camera is stored below 0°C.

The camera should be stored in a dry environment with the temperature ranging from -50°C to + 90°C.

CAUTION ⚠️

1. Avoid direct exposure to moisture and liquids. The camera housing is not hermetically sealed and any exposure to liquids may damage the camera electronics!
2. Avoid operating in an environment without any air circulation, in close proximity to an intensive heat source, strong magnetic or electric fields.
3. Avoid touching or cleaning the front surface of the optical sensor. To clean the sensor, use only a soft lint-free cloth and an optical cleaning fluid. **Do not use methylated alcohol!**

3 GenICam API Configurator

3.1 Overview

Cheetah cameras are programmable and flexible. You can monitor and control all of the camera's resources such as internal registers, features, video amplifiers, parameter flash, and so on.

3.2 Camera Configuration Memory

3.2.1 Parameter Flash

The camera has a built-in configuration memory divided into four segments: Work Space, Factory Space, User Space #1, and User Space #2. The Work Space segment contains the current camera settings while the camera is powered up and operational. All camera registers are located in this space. You can program these registers and issue commands to retrieve data.

The Work Space is RAM based. All camera registers clear upon camera power-down. The Factory Space segment is ROM based, write protected, and contains the default camera settings. This space is available for read operations only. User Space #1 and User Space #2 are non-volatile, flash-based, and used to store two user-defined configurations or User Sets. Upon power up or software reset, the camera firmware loads the Work Space registers from the Factory Space, User Space #1, or User Space #2 as determined by a User Set Default Selector setting. At any time, you can instruct the camera to load its Work Space with the contents of the Factory Space, User Space #1, or User Space #2 using the User Set Load command. You can instruct the camera to save the current Work Space settings into either User Space #1 or User Space #2 using the User Set Save command.

The non-volatile parameter Flash memory also contains the Defective Pixel Map, Hot Pixel Map, LUT 1, and LUT 2, which can be loaded to the camera internal memory upon enabling the corresponding camera feature. You can create your own DPM, HPM, and LUT tables and upload them to the parameter Flash using the Imperx Upload Utility.

3.3 Starting up the Camera

Upon power on or receipt of a 'SW_Reset' command, the camera performs the following steps:

1. Boot loader checks program flash memory for a valid firmware image and loads it into the field-programmable gate array (FPGA).
2. The camera reads the Boot From register from the parameter flash and loads its workspace from one of the configuration spaces determined by the User Set Default Selector. Configuration spaces are: Factory, User #1, User #2.
3. The camera is initialized and ready to accept user commands.

3.4 Configuring the CXP Camera

Cheetah CoaXPress (CXP) cameras include an embedded Extensible Markup Language (XML) camera description file. The XML file contains all of the information required to automatically map a camera's features to its internal registers. The GenICam^{TM} standard defines the syntax and semantics of the camera description file and provides a mechanism for you to configure the camera by reading/writing the camera registers associated with the features.

Your frame grabber should provide a GenICam compliant player that displays the XML parameters and enables you to configure the camera. When connected to the frame grabber, the camera transfers the XML file to the frame grabber host application.

The XML file contains a set of nodes, with each set representing features and parameters of the camera. Each node has a set of attributes that define the feature, including a description, type (i.e. integer, Boolean, etc.), values, and access mode for the parameter (RW: Read/Write, RO: Read Only, WO: Write Only).

NOTE ✱

In the following tables, parameter names underlined in *red bold italic* letters indicate that you must turn image acquisition **off** in order to change the parameters. After making changes, you can turn the camera image acquisition back **on**.

3.4.1 Device Control

Device Control gives you information about the camera and the GenICam compliant XML file that gives you control over the CXP camera. Most of the Device Control information is read-only except for the Device Reset and Camera Head Reset functions.
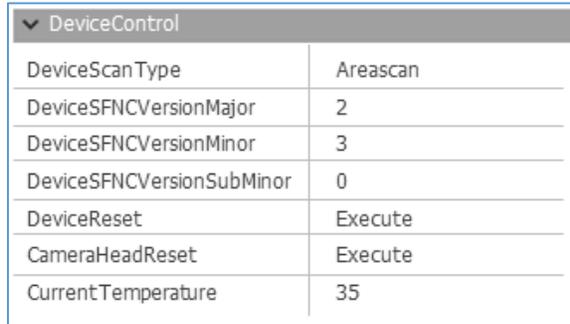
Figure 19: Device Control screen example.

Parameter Name	Type	Value		Access	Description
DeviceScanType	Enumeration	**String** "Areascan"	**Num.** 0	RO	Specifies sensor scan type.
DeviceSFNCVersionMajor	Integer			RO	Major version of Standard Features Naming Convention used to create camera's GenICam XML.
DeviceSFNCVersionMinor	Integer			RO	Minor version of Standard Features Naming Convention used to create camera's GenICam XML.
DeviceSFNCVersionSubMinor	Integer			RO	Sub minor version of Standard Features Naming Convention used to create camera's GenICam XML.
DeviceReset	Command			WO	Resets camera head and CXP engine and puts camera in power-up state.
CameraHeadReset	Command			WO	Resets the camera's circuitry (CXP Engine does not reset). After resetting the camera, you should issue a UserSetLoad command.
CurrentTemperature	Integer			RO	Returns current camera temperature as a 2's complement number. *

*The temperature range is +127C to -128C. A value greater than 127 indicates a negative temperature. To calculate the negative temperature, subtract 255 from the value. For example, a value of 254 indicates a temperature of 255-254 = -1 degree C.

3.4.2 Version Info

Version Info parameters provide read-only information identifying the camera's firmware, hardware, software, image sensor, camera version, CXP support, and so on.

VersionInfo	
SensorType	Monochrome
RgsID	24578
FpgaID	7
EpcsID	2
FirmwareVersion	56
FirmwareBuild	44
FirmwareImage	0
CameraHeadFirmwareVersion	56
CameraHeadFirmwareBuild	43
CustomerID	0
FamilyID	3
XmlVersion	104
CXPCoreVersion	458765
CxpSupport	
Standard	0x0
Revision	0x10001
XmlManifestSize	1
XmlManifestSelector	0
XmlSchemaVersion	65536
XmlUrlAddress	805306368
IidcPointer	0

Figure 20: Version Info screen example.

Parameter Name	Type	Value		Access	Description
SensorType	Enumeration	**String** "Monochrome" "Bayer"	**Num.** 0 1	RO	Returns the CMOS sensor type.
RgsID	Integer			RO	Returns the RGS ID register.
FpgaID	Integer			RO	Returns the FPGA ID.
EpcsID	Integer			RO	Returns the EPCS ID.
FirmwareVersion	Integer			RO	Returns the Firmware version number.
FirmwareBuild	Integer			RO	Returns the Firmware build number.
FirmwareImage	Integer			RO	Returns the Firmware Image ID (F=Factory or A=Application).
CameraHeadFirmwareVersion	Integer			RO	Returns the CameraHead Firmware version number.

Parameter Name	Type	Value	Access	Description
CameraHeadFirmwareBuild	Integer		RO	Returns the CameraHead Firmware build number.
CustomerID	Integer		RO	Returns the Customer ID for custom firmware (0=Imperx standard firmware)
FamilyID	Integer		RO	Returns the Family ID.
XmlVersion	Integer		RO	Returns the version of the XML file.
CxpCoreVersion	Integer		RO	Returns the CXP Firmware version number.

Version Info_CXP Support

Parameter Name	Type	Value	Access	Description
Standard	Integer		RO	Returns CoaXPress "magic" number.
Revision	Integer		RO	Returns revision of the CoaXPress specification implemented in this device.
XmlManifestSize	Integer		RO	Returns the number of XML manifests available in this device.
XmlManifestSelector	Integer		RO	Returns the number of the selected XML manifest.
XmlSchemaVersion	Integer		RO	Returns the GenICam schema version for the XML.
XmlUrlAddress	Integer		RO	Returns the address of the start of the URL string which points to the XML file.
IidcPointer	Integer		RO	Returns the address of the start of the IIDC register space.

3.4.3 Image Format Control

Image Format Control lets you change screen resolution, apply binning to image output, select camera bit depth, and more.
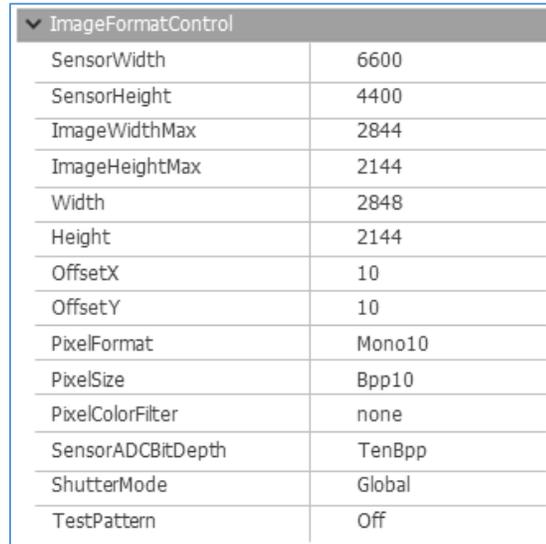
Figure 21: Image Format Control screen sample.

Parameter Name	Type	Value	Access	Description
SensorWidth	Integer		RO	Effective width of the sensor in pixels.
SensorHeight	Integer		RO	Effective height of the sensor in pixels.
ImageWidthMax	Integer		RO	Maximum width of the image (in pixels) calculated after horizontal binning, decimation, or any other function changing the horizontal dimension of the image.
ImageHeightMax	Integer		RO	Maximum height of the image (in pixels) calculated after vertical binning, decimation or any other function changing the vertical dimension of the image.
Width	Integer	Min: 16 Max: ImageWidthMaxReg	RW	Represents the actual image width expelled by the camera of the master AOI (in pixels).
Height	Integer	Min: 2 Max: ImageHeightMaxReg	RW	Represents the actual image height expelled by the camera of the master AOI (in pixels).

Parameter Name	Type	Value		Access	Description
OffsetX	Integer	Min: 0 Max: OffsetX_MaxExpr		RW	Sets the horizontal distance of the image from the left side of the field of view (in pixels).
OffsetY	Integer	Min: 0 Max: OffsetY_MaxExpr		RW	Sets the vertical distance of the image from the top side of the view of view (in pixels).
PixelFormat	Enumeration	**String** "Mono8" "Mono10" "Mono12" "BayerGR8" "BayerGR10" "BayerGR12"	**Num.** 0x01080001 0x01100003 0x01100005 0x01080008 0x0110000C 0x01100010	RW	Indicates the format of the pixel to use during the acquisition. Note: If using a 12-bit pixel format, set SensorADCBitDepth to TwelveBpp.
PixelSize	Enumeration	**String** "Bpp8" "Bpp10" "Bpp12"	**Num.** 0 1 2	RO	Indicates the total size in bits of a pixel of the image.
PixelColorFilter	Enumeration	**String** "None" "BayerRG" "BayerGB" "BayerGR" "BayerBG"	**Num.** 0 1 2 3 4	RO	Indicates the type of color filter that is applied to the image.
SensorADCBitDepth	Enumeration	**String** "TenBpp" "TwelveBpp"	**Num.** 1 2	RW	Sets the bit depth of the sensor's ADC.
ShutterMode	Enumeration	**String** "Rolling" "Global"	**Num.** 0 1	RW	Selects the operation mode of the sensor's shutter.
TestPattern	Enumeration	**String** "Off" "GreyHorizontalRamp" "GreyVerticalRamp" "GreyHorizontalRampMoving" "GreyVerticalRampMoving" "Crosshair"	**Num.** 0 1 2 3 4 5	RW	Selects the type of test pattern that is generated by the device as image source.

3.4.4 Acquisition Control

Acquisition Control lets you configure settings for image capture, exposure, frame rates, triggers, and so on. It also provides a variety of read-only information.

Figure 22: Acquisition Control screen example.

Parameter Name	Type	Value		Access	Description
AcquisitionMode	Enumeration	**String** "Continuous"	**Num.** 0	RO	Sets the acquisition mode of the device. It defines mainly the number of frames to capture during an acquisition and the way the acquisition stops.
AcquisitionStart	Command			WO	Starts the Acquisition of the device.
AcquisitionStop	Command			WO	Stops the Acquisition of the device at the end of the current Frame.
ExposureMode	Enumeration	**String** "Off" "TriggerWidth" "Timed"	**Num.** 0 1 2	RW	Sets the operation mode of the Exposure.

Parameter Name	Type	Value		Access	Description
ExposureTime	Float	Min:	4.0	RW	Sets the Exposure time in microseconds when ExposureMode is Timed and ExposureAuto is Off
		Max:	ExposureMaxExpr		
AcquisitionFrameRateEnable	Boolean			RW	Controls if the AcquisitionFrameRate and AcquisitionFramePeriod features are writable and used to control the acquisition rate. If this mode is ON, user can extend the actual frame time beyond the free-running frame time.
AcquisitionFrameTime	Integer	Min:	MinFrameTimeReg	RW	Sets the actual frame time in us.
		Max:	MaxFrameTimeReg		
AcquisitionFrameTimeMax	Integer			RO	Returns maximum frame time in microseconds.
AcquisitionFrameTimeMin	Integer	Min:	MinFrameTimeReg	RO	Returns frame time min. time in microseconds.
		Max:	1000000		
AcquisitionFrameRate	Float	Min:	0.9999999	RO	Returns the acquisition rate (in Hertz) at which the frames are captured.
		Max:	FrameRateMaxExpr		
CurrentExposureTime	Integer			RO	Returns the current exposure time in units of micro-seconds.
CurrentFrameTime	Integer			RO	Returns the current frame time in units of micro-seconds.
LineTime	Integer	Min:	LineTimeMin	RW	Sets the imager's line time in units of clocks.
		Max:	16384		
LineTimeMin	Integer			RO	Returns imager's line time in units of clocks.
TriggerMode	Enumeration	**String**	**Num.**	RW	Enables the Trigger mode of operation.
		"Off"	0		
		"On"	1		
TriggerSoftware	Command			WO	Generates an internal trigger. Trigger Source must be set to Software.
TriggerSource	Enumeration	**String**	**Num.**	RW	Specifies the internal signal or physical input Line to use as the trigger source. The selected trigger must
		"Line1"	0		
		"Line2"	1		
		"CxpTrigger"	2		

Parameter Name	Type	Value		Access	Description
		"PulseGenerator"	4		have TriggerMode set to On.
		"Software"	5		
TriggerActivation	Enumeration	**String**	**Num.**	RW	Specifies the activation mode of the trigger.
		"RisingEdge"	0		
		"FallingEdge"	1		
TriggerDebounce	Enumeration	**String**	**Num.**	RW	Specifies the debounce period of the trigger signal.
		"Disabled"	0		
		"TenMicroSeconds"	1		
		"FiftyMicroSeconds"	2		
		"OneHundredMicroSeconds"	3		
		"FiveHundredMicroSeconds"	4		
		"OneMilliSecond"	5		
		"FiveMilliSeconds"	6		
		"TenMilliSeconds"	7		

3.4.5 Gain Control

Gain Control provides parameters for setting analog gain, black level raw, and digital gain.
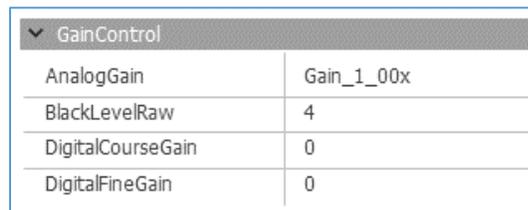
Figure 23: Gain Control screen example.

Parameter Name	Type	Value		Access	Description
AnalogGain	Enumeration	**String**	**Num.**	RW	Controls the Analog Gain for all taps.
		"Gain_1_00x"	32		
		"Gain_1_07x"	30		
		"Gain_1_14x"	28		
		"Gain_1_23x"	26		
		"Gain_1_33x"	24		
		"Gain_1_45x"	22		
		"Gain_1_60x"	20		
		"Gain_1_77x"	18		
		"Gain_2_00x"	16		

Parameter Name	Type	Value	Access	Description
		"Gain_2_28x" 14 "Gain_2_66x" 12 "Gain_3_20x" 10 "Gain_4_00x" 8 "Gain_5_33x" 6 "Gain_8_00x" 4		
BlackLevelRaw	Integer	Min: 0 Max: 16383	RW	Controls the Black Level for all taps.
DigitalCourseGain	Integer	Min: 0 Max: 3	RW	Controls the course Digital Gain for all taps.
DigitalFineGain	Integer	Min: 0 Max: 63	RW	Controls the fine Digital Gain for all taps.

3.4.6 Data Correction

Data Correction parameters enable you to implement tables and other techniques to improve image sensor performance.

Figure 24: Data Correction screen example.

Parameter Name	Type	Value		Access	Description
LUTSelector	Enumeration	**String** "LUT1" "LUT2"	**Num.** 0 1	RW	Selects the LUT to be controlled by the LUTEnable feature.
LUTEnable	Boolean			RW	Activates the selected LUT.
DefectPixelCorrection	Enumeration	**String** "Off" "Static" "Dynamic" "Both"	**Num.** 0 1 2 3	RW	Enables Defective Pixel Correction.

Parameter Name	Type	Value		Access	Description
DefectPixelThreshold	Integer	Min: 0 Max: 4095		RW	Sets the threshold for the Defect Pixel Correction algorithm.
HotPixelCorrection	Enumeration	**String** "Off" "Static" "Dynamic" "Both"	**Num.** 0 1 2 3	RW	Enables Hot Pixel Correction.
HotPixelThreshold	Integer	Min: 0 Max: 4095		RW	Sets the threshold for the Hot Pixel Correction algorithm.

3.4.7 White Balance

White Balance parameters give you control over the individual red, green, and blue colors produced by the sensor in color cameras.
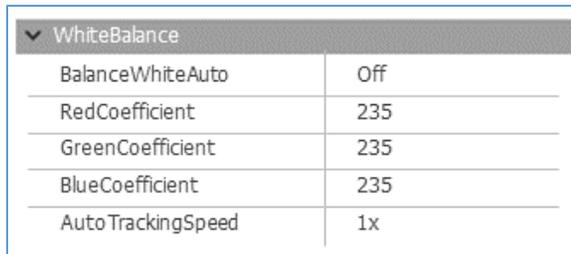
Figure 25: White Balance screen example.

Parameter Name	Type	Value		Access	Description
BalanceWhiteAuto	Enumeration	**String** "Off" "Once" "Continuous" "Manual"	**Num.** 0 1 2 3	RW	Controls the mode for automatic white balancing between color channels. White balancing ratios are adjusted automatically.
RedCoefficient	Integer	Min: 0 Max: 4095		RW	Sets white balance coefficient for the Red channel (when WhiteBalanceMode is Manual).
GreenCoefficient	Integer	Min: 0 Max: 4095		RW	Sets white balance coefficient for the Green channel (when BalanceWhiteAuto is Manual).
BlueCoefficient	Integer	Min: 0 Max: 4095		RW	Sets white balance coefficient for the Blue channel (when BalanceWhiteAuto is Manual).
AutoTrackingSpeed	Enumeration	**String** "x1"	**Num.** 0	RW	Controls speed of auto white balance loop when

Parameter Name	Type	Value		Access	Description
		"x2"	1		BalanceWhiteAuto=Auto, where x1=slowest and x5=fastest.
		"x3"	2		
		"x4"	3		
		"x5"	4		

3.4.8 Strobe

Use strobe XML parameters to activate and control strobe performance and outputs.
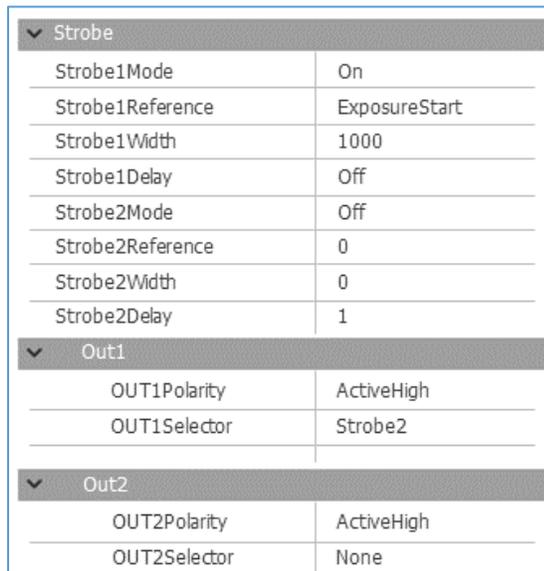
Figure 26: Strobe screen example.

Parameter Name	Type	Value		Access	Description
Strobe1Mode	Enumeration	**String** "Off" "On"	**Num.** 0 1	RW	Sets the Strobe #1 mode of operation.
Strobe1Reference	Enumeration	**String** "ExposureStart" "ReadoutStart"	**Num.** 0 1	RW	Sets the reference point for Strobe1.
Strobe1Width	Integer	Min: 1 Max: 1000000		RW	Sets the pulse duration for Strobe1 in units of microseconds.
Strobe1Delay	Integer	Min: 0 Max: 1000000		RW	Sets the delay from the reference for Strobe1 in units of microseconds.
Strobe2Mode	Enumeration	**String** "Off"	**Num.** 0	RW	Sets the Strobe #2 mode of operation.

Parameter Name	Type	Value		Access	Description
		"On"	1		
Strobe2Reference	Enumeration	**String**	**Num.**	RW	Sets the reference point for Strobe2.
		"ExposureStart"	0		
		"ReadoutStart"	1		
Strobe2Width	Integer	Min: 0		RW	Sets the pulse duration for the Strobe2 in units of microseconds.
		Max: 1000000			
Strobe2Delay	Integer	Min: 0		RW	Sets the delay from the reference for Strobe2 in units of microseconds.
		Max: 1000000			

Strobe OUT1

Parameter Name	Type	Value		Access	Description
OUT1Polarity	Enumeration	**String**	**Num.**	RW	Sets the active logic level of the OUT1 output.
		"ActiveLow"	0		
		"ActiveHigh"	1		
OUT1Selector	Enumeration	**String**	**Num.**	RW	Maps internal signals to the OUT1 output.
		"None"	0		
		"Trigger"	1		
		"PulseGenerator"	2		
		"Strobe1"	3		
		"Strobe2"	4		

Strobe OUT2

Parameter Name	Type	Value		Access	Description
OUT2Polarity	Enumeration	**String**	**Num.**	RW	Sets the active logic level of the OUT2 output.
		"ActiveLow"	0		
		"ActiveHigh"	1		
OUT2Selector	Enumeration	**String**	**Num.**	RW	Maps internal signals to the OUT2 output.
		"None"	0		
		"Trigger"	1		
		"PulseGenerator"	2		
		"Strobe1"	3		
		"Strobe2"	4		

3.4.9 Pulse Generator

The camera provides an internal pulse generator for generating a trigger signal. You can program it to generate a discrete sequence or a continuous trail of pulse signals.

Figure 27: Pulse Generator screen example.

Parameter Name	Type	Value		Access	Description
PulseGenGranularity	Enumeration	**String** "x1uS" "x10uS" "x100uS" "x1000uS"	**Num.** 0 1 2 3	RW	Sets the multiplication factor of the Pulse Generator where x1 = 1uS, x10=10uS, etc.
PulseGenWidth	Integer	Min: PulseGenMin Max: PulseGenWidthMax		RO	Returns the pulse width of the Pulse Generator in microseconds.
PulseGenPeriod	Integer	Min: PulseGenMin Max: PulseGenPeriodMax		RO	Returns the pulse period of the Pulse Generator in microseconds
PulseGenNumPulses	Integer	Min: 1 Max: 65535		RW	Sets the number of pulses the Pulse Generator is to produce.
PulseGenMode	Enumeration	**String** "Continuous" "NumPulses"	**Num.** 0 1	RW	Sets the Pulse Generator to provide either continuous operation or a set number of pulses.
PulseGenEnable	Boolean			RW	Enables Pulse Generator. You can map pulse generator output to OUT1 or OUT2 output signals.

3.4.10 Wide Dynamic Range

Wide dynamic range (WDR) enables setting different exposure times for pixels of different intensities within one exposure time, for example, setting a short exposure time for ultra-bright pixels.

WideDynamicRange	
WdrEnable	False
WdrP1	FortyFive
WdrP2	Sixty
WdrP3	SeventyFive
WdrE1	1000
WdrE2	2000
WdrE3	4000

Figure 28: Wide Dynamic Range screen example.

Parameter Name	Type	Value		Access	Description
WdrEnable	Boolean			RW	Enables the WDR mode.
WdrP1	Enumeration	**String**	**Num.**	RW	Sets the WDR's P1 value in units of percent.
		"OneHundred"	0		
		"Ninety"	1		
		"Eighty"	2		
		"SeventyFive"	3		
		"Seventy"	4		
		"SixtyFive"	5		
		"Sixty"	6		
		"FiftyFive"	7		
		"Fifty"	8		
		"FortyFive"	9		
		"Forty"	10		
		"ThirtyFive"	11		
		"Thirty"	12		
		"TwentyFive"	13		
		"Twenty"	14		
		"Fifteen"	15		
WdrP2	Enumeration	**String**	**Num.**	RW	Sets the WDR's P2 value in units of percent.
		"OneHundred"	0		
		"Ninety"	1		
		"EightyFive"	2		
		"SeventyFive"	3		
		"Seventy"	4		
		"SixtyFive"	5		
		"Sixty"	6		

Parameter Name	Type	Value		Access	Description
		"FiftyFive"	7		
		"Fifty"	8		
		"FortyFive"	9		
		"Forty"	10		
		"ThirtyFive"	11		
		"Thirty"	12		
		"TwentyFive"	13		
		"Twenty"	14		
		"Fifteen"	15		
WdrP3	Enumeration	**String**	**Num.**	RW	Sets the WDR's P3 value in units of percent.
		"OneHundred"	0		
		"Ninety"	1		
		"Eighty"	2		
		"SeventyFive"	3		
		"Seventy"	4		
		"SixtyFive"	5		
		"FiftyFive"	7		
		"Fifty"	8		
		"FortyFive"	9		
		"Forty"	10		
		"ThirtyFive"	11		
		"Thirty"	12		
		"TwentyFive"	13		
		"Twenty"	14		
		"Sixty"	6		
		"Fifteen"	15		
WdrE1	Integer	Min: 4 Max: WdrE2Reg		RW	Sets the WDR's E1 value in units of microseconds.
WdrE2	Integer	Min: WdrE1Reg Max: WdrE3Reg		RW	Sets the WDR's E2 value in units of microseconds.
WdrE3	Integer	Min: WdrE2Reg Max: CurrentExposureTimeReg		RW	Sets the WDR's E2 value in units of microseconds.

3.4.11 Transport Layer Control

The Transport Layer control provides a variety of configuration settings and read-only information for configuring communications between the camera with the CXP interface.

TransportLayerControl	
DeviceTapGeometry	Geometry_1X_1Y
CoaXPress	
WidthAddress	0x10000044
HeightAddress	0x1000004C
AcquisitionModeAddress	0x1000001C
AcquisitionStartAddress	0x10000020
AcquisitionStopAddress	0x10000024
PixelFormatAddress	0x1000060C
DeviceTapGeometryAddress	0x1000002C
Image1StreamIDAddress	0x10000030
Image1StreamID	1
ConnectionReset	Execute
DeviceConnectionID	0
MasterHostConnectionID	65792
ControlPacketSizeMax	280
StreamPacketSizeMax	8192
CxpLinkConfiguration	CXP3_X1
CxPConfigurationPreferred	CXP3_X1
CXPConnectionTestMode	False
CxpConnectionSelector	0
CxpConnectionTestErrorCount	0
CxpConnectionTestPacketCount	0
CxpConnectionTestPacketCountTx	0
LastErrorLatched	0x0
KErrorCount	2
RDErrorCount	3
CXPErrorCount	2
XSizeCXPLink	6600
XOffsetCXPLink	0
YSizeCXPLink	4400
YOffsetCXPLink	0
PixelFormatCXPLink	0x101

Figure 29: Transport Layer CoaXPress screen example.

Parameter Name	Type	Value		Access	Description
DeviceTapGeometry	Enumeration	**String** "Geometry_1X_1Y"	**Num.** 0	RO	Device Tap Geometry describes the geometrical properties characterizing the taps of a camera as presented at the output of the device.

Transport Layer Control_CoaXPress

Parameter Name	Type	Value		Access	Description
WidthAddress	Integer			RO	Returns the address of the Width information register.
HeightAddress	Integer			RO	Returns the address of the Height information register.
AcquisitionModeAddress	Integer			RO	Returns the address of the AcquisitionMode information register.
AcquistionStartAddress	Integer			RO	Returns the address of the AcquistionStart command register.
AcquistionStopAddress	Integer			RO	Returns the address of the AcquistionStop command register.
PixelFormatAddress	Integer			RO	Returns the address of the PixelFormat information register.
DeviceTapGeometryAddress	Integer			RO	Returns the address of the DeviceTapGeometry information register.
Image1StreamIDAddress	Integer			RO	Returns the address of the Image1StreamID information register.
Image1StreamID	Integer			RO	Returns the Stream ID as the primary image stream from the device.
ConnectionReset	Command			RW	Activates the Link Reset procedure.
DeviceConnectionID	Integer			RO	Returns the ID of the device link.
MasterHostConnectionID	Integer			RO	Returns the Host link ID connected to this device's master link.
ControlPacketSizeMax	Integer			RO	Returns the maximum control packet data size that the device can accept.
StreamPacketSizeMax	Integer			RW	Returns the maximum stream packet data size that the host can accept.
CxpLinkConfiguration	Enumeration	**String** "CXP1_X1" "CXP2_X1" "CXP3_X1"	**Num.** 0x00010028 0x00010030 0x00010038	RW	Allows you to specify the Link configuration for communications between the receiver and transmitter device. In most cases, this

Parameter Name	Type	Value		Access	Description
		"CXP5_X1"	0x00010040		feature does not need to be written because automatic discovery will set the configuration correctly to the value returned by CxpLinkConfigurationPreferred. Note: the currently active configuration of the Link can be read using CxpLinkConfigurationStatus.
		"CXP6_X1"	0x00010048		
		"CXP1_X2"	0x00020028		
		"CXP2_X2"	0x00020030		
		"CXP3_X2"	0x00020038		
		"CXP5_X2"	0x00020040		
		"CXP6_X2"	0x00020048		
CxpLinkConfigurationPreferred	Enumeration	**String**	**Num.**	RO	Provides the Link configuration that allows the transmitter device to operate in its default mode.
		"CXP1_X1"	0x00010028		
		"CXP2_X1"	0x00010030		
		"CXP3_X1"	0x00010038		
		"CXP5_X1"	0x00010040		
		"CXP6_X1"	0x00010048		
		"CXP1_X2"	0x00020028		
		"CXP2_X2"	0x00020030		
		"CXP3_X2"	0x00020038		
		"CXP5_X2"	0x00020040		
		"CXP6_X2"	0x00020048		
CxpConnectionTestMode	Boolean			RW	Enables test mode for an individual physical connection of the device.
CxpConnectionSelector	Integer	Min: 0 Max: CxpMaxConnectionsExpr		RW	Selects the CoaXPress physical connection to control.
CxpConnectionTestErrorCount	Integer			RW	Reports the current connection error count for test packets received by the device on the connection selected by CxpConnectionSelector.
CxpConnectionTestPacketCount	Integer			RW	Reports the current count for test packets received by the device on the connection selected by CxpConnectionSelector.
CxpConnectionTestPacketCountTx	Integer			RW	Reports the current count for test packets sent by the device on the connection selected by CxpConnectionSelector.
LastErrorLatched	Integer			RO	Returns the low-speed link's last CXP error.

Parameter Name	Type	Value		Access	Description
KErrorCount	Integer			RW	Returns the low-speed link's current 8B10B K-Code error count. Writing a 0x0 clears the error counter.
RDErrorCount	Integer			RW	Returns the low-speed link's current 8B10B Running-Disparity error count. Writing a 0x0 clears the error counter.
CXPErrorCount	Integer			RW	Returns the low-speed link's current CXP protocol error count. Writing a 0x0 clears the error counter.
XSizeCXPLink	Integer			RO	Returns the Horizontal image size in the CXP link.
XOffsetCXPLink	Integer			RO	Returns the Horizontal image offset in the CXP link.
YSizeCXPLink	Integer			RO	Returns the Vertical image size in the CXP link.
YOffsetCXPLink	Integer			RO	Returns the Vertical image offset in the CXP link.
PixelFormatCXPLink	Integer			RO	Returns the Pixel Format in the CXP link.

Transport Layer_CoaXPress Customization
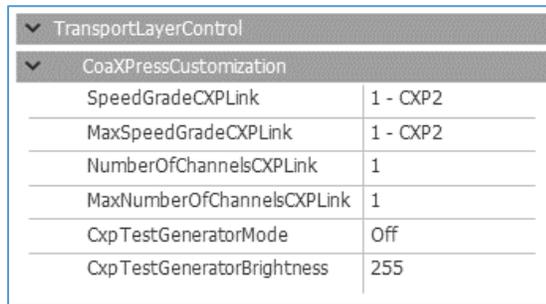
Figure 30: Transport Layer CXP Customization screen example.

Parameter Name	Type	Value		Access	Description
SpeedGradeCXPLink	Integer	Min: Max:	1 MaxSpeedGradeCXPLinkReg	RW	Sets the speed grade of the CXP link, 1 - CXP2, 2 - CXP3, 3 - CXP5, 4 - CXP6. Changes take effect after the power cycle or DeviceReset command run.
MaxSpeedGradeCXPLink	Integer			RO	Returns the Maximum speed grade of the CXP link.

Parameter Name	Type	Value		Access	Description
NumberOfChannelsCXPLink	Integer	Min:	0	RW	Sets the number of channels of the CXP link; 0 - X1, 1 - X2. Changes take effect after the power cycle or DeviceReset command run.
		Max:	MaxSpeedGradeCXPLinkReg		
MaxNumberOfChannelsCXPLink	Integer			RO	Returns the Maximum number of channels of the CXP link.
CxpTestGeneratorMode	Enumeration	String	Num.	RW	Represents the operation mode of CXP engine test image generator.
		"Off"	0		
		"Mode_0"	1		
		"Mode_1"	2		
		"Mode_2"	3		
CxpTestGeneratorBrightness	Integer	Min:	0	RW	Represents the brightness of CXP engine test image generator.
		Max:	4095		

3.4.12 User Set Control

User Set Control allows you to save custom settings and reload them into the camera as needed.
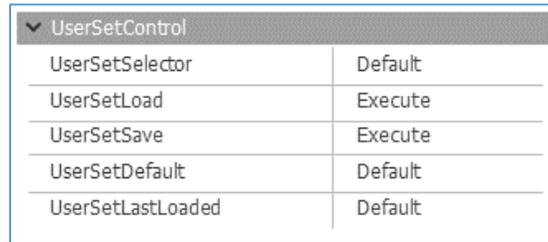
Figure 31: User Set Control screen example.

Parameter Name	Type	Value		Access	Description
UserSetSelector	Enumeration	String	Num.	RO	Returns the User Set to load, save, or configure.
		"Default"	0		
		"UserSet0"	1		
		"UserSet1"	2		
UserSetLoad	Command			WO	Loads the User Set specified by UserSetSelector to the device and makes it active.
UserSetSave	Command			WO	Saves the User Set specified by UserSetSelector to the non-volatile memory of the device.
UserSetDefault	Enumeration	String	Num.	RW	Selects the User Set to load and make active when the device is reset.
		"Default"	0		
		"UserSet0"	1		
		"UserSet1"	2		

Parameter Name	Type	Value		Access	Description
UserSetLastLoaded	Enumeration	**String**	**Num.**	RO	Returns the User Set currently loaded (from the last UserSetLoad command or device reset).
		"Default"	0		
		"UserSet0"	1		
		"UserSet1"	2		
		"UserSet2"	3		
		"UserSet3"	4		

3.4.13 Special Features

The Special Features parameters provide status information on the camera and on GenICam transport layer streaming.
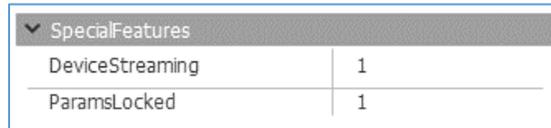
Figure 32: Special Features screen example.

Parameter Name	Type	Value	Access	Description
DeviceStreaming	Integer		RO	Returns the state of the camera streaming interface: 1 when grabbing; 0 when not.
ParamsLocked	Integer		RO	Returns the state of the GenTL or camera streaming interface: 1 when grabbing; 0 when not.

4 Camera Features

4.1 Global / Rolling Shutter

The C2880 and C4080 cameras support both rolling and global shutter operational modes.

In global shutter operational mode, all lines (and pixels) within the imaging array reset at the same time and are then exposed. Readout follows exposure, then, lines read out of the array sequentially. In this mode, every pixel in the array is exposed during the same time period as determined by the cameras exposure control setting. This is useful if an object within the scene is moving, since all pixels within the array capture the image at the same instant in time. Global shutter introduces more noise into the image and therefore is not as sensitive as rolling shutter operation.

In rolling shutter mode, the camera resets and exposes each line in the imaging array at a slightly different time period. If there is motion within the scene, this can result in distortions to the object in motion. The size of these distortions will vary based on the read-out rate of the camera and the speed of the object in motion. Many applications are not sensitive to these slight distortions. Rolling shutter mode has much more sensitivity compared to global shutter mode and is useful in light starved applications.

4.2 ADC Digitization

You can select the analog-to-digital converter (ADC) digitization level within the image sensor to trade off dynamic range for frame rate. If selecting a 12-bit digitization level, the maximum frame rate drops to about 26 frames per second, limited by the ADC settling time. If setting the ADC selector to 10-bits, the ADC settling time decreases, and the maximum camera output frame rate increases.

4.3 Frame Time Control

4.3.1 Internal Line and Frame Time Control

The camera speed (frame rate) depends on the CMOS read-out time, which is the time necessary to read all the pixels out of the CMOS imager. The frame rate calculation uses the following Formula:

$$\text{Frame rate [fps]} = 1 / \text{read-out time [sec]} \qquad (1.1)$$

You can program the camera to run slower than the nominal speed, thus preserving the camera full resolution by extending the camera line time (the time required to read one line out of the CMOS imager) and camera frame time (the time required to read the entire frame out of the CMOS imager). If the sensor read-out speed exceeds the CoaXPress interface output rate, the camera automatically sets a minimum line time consistent with the available bandwidth of the CoaXPress output interface. If the computer is losing data,

increase the line time control to match the computer's acquisition rate to the Cheetah camera output rate.

With the Fixed Frame Period control enabled, you can increase the frame time from the camera-determined minimum frame time to a maximum of 1 sec, with a precision of ~ 1.0µs. In this way, you can reduce the output frame rate to match the application requirements.

4.3.2 Camera Output Control

The CXP output interface transfers data at 6.25 per channel (two channels available). With 8b/10b encoding to achieve DC-Balance and allow reasonable clock recovery, the maximum theoretical data rate is 5Gbps. If the camera output rate exceeds the CXP interface bandwidth, adjust the camera line rate using the Line Time control to match the camera output rate to the CXP transfer rate.

CoaXPress hardware and drivers vary considerably between manufacturers and with firmware overhead, therefore, the practical data bit rates range between 2.6 gigabits per second and 3.2 gigabits per second (depending upon the hardware and drivers within the receiving computer). The camera Line Time settings, combined with the output bit-depth (8, 10, or 12-bit), control the total interface bandwidth.

The following table describes tested CoaXPress full frame rates for CXP-6, DIN2 configuration.

Camera	Bit Depth	Full Resolution CoaXPress Interface (fps max)
C4080	8	70.0
	10	60.2
	12	31.5
C2880	8	160
	10	118
	12	44.7

Table 6: Typical frame rate versus bit depth.

4.4 Area of Interest

4.4.1 Overview

For some applications, you might not need the entire image, but only a portion of it. To accommodate this requirement, Cheetah cameras provide one region of interest, also known as Area of Interest (AOI). An AOI is a unique field of view created within the camera's maximum field of view. The cameras also allow custom AOI as described below.

4.4.2 AOI Horizontal and Vertical Window

You can set the starting and ending point for each AOI independently in a horizontal direction (Horizontal Window) and in a vertical direction (Vertical Window) by setting the window (H & V) offset and (H & V) size. The minimum window size is 320 (H) x 2 (V) pixel/line, and the horizontal dimension is limited to multiples of 8 pixels. In normal operation, the AOI defines the number of columns and rows output. However, you can apply subsampling and averaging modes to the AOI to reduce the number of rows and columns output even further. Using the AOI function and subsampling/averaging modes effectively increases the camera frame rate. The maximum horizontal window size (H) and the vertical window size (V) are determined by the camera's image full resolution, for example, the C5180 camera's resolution of 5120 x 5120.
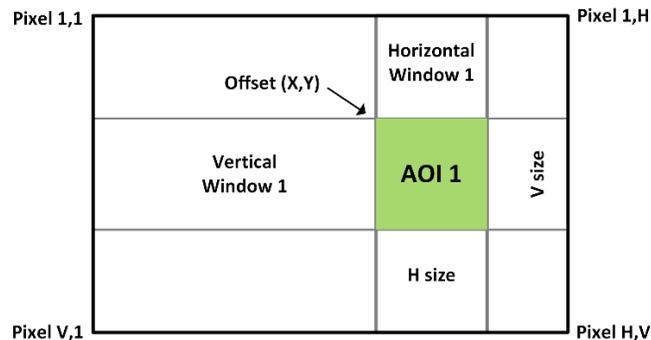
Figure 33: Horizontal and vertical window positioning.

TIP ⓘ

For color cameras with AOI enabled, you must use an even number for Offset X and Offset Y to achieve proper color reconstruction and white balance.

4.4.3 Factors Impacting AOI Frame Rate

The camera frame rate depends upon a number of variables including the exposure time, number of rows and columns in the AOI, the amount of decimation within the image, and the bandwidth of the output interface.

AOI size: You can increase the camera frame rate by decreasing either the number of columns or number of rows read out. Changing the number of rows read out causes the largest change in frame rate.

Exposure Time: In free-running mode, the camera overlaps the exposure time and image readout. In trigger mode, the exposure and readout time do not overlap, and long exposure times will decrease frame rate.

Decimation: The camera supports both subsampling and pixel averaging to reduce the output resolution. Pixel averaging does not increase the image sensor frame rate because all of the pixels must be read out and averaged together. However, subsampling decimation can offer a frame rate improvement by reducing the number of rows read out from the image sensor.

A/D Bit Depth: The image sensor has an A/D converter on each column of the image sensor and reads out two rows (one line) simultaneously. There is a finite time required to reach convergence depending upon the A/D digitization level selected, and this can affect the maximum frame rate.

The time required to digitize two rows:
1) 10-bit digitization: approximately 9 microseconds
2) 12-bit digitization: approximately 20 microseconds

For example, if you select 12-bit digitization, the camera can digitize two rows (one line) in 20 microseconds. For example, since the C4080 must read out 3136 rows (1,568 lines), digitizing the entire image array consumes 31mS per frame, and the frame rate is limited accordingly.

Output Interface Bandwidth: The bandwidth of the output interface can affect the maximum achievable frame rate. For example, the CoaXPress interface bandwidth of approximately 3.0 gigabits per second limits the frame rate.

Triggered and Triggered Dual Video Mode: The camera normally overlaps the exposure time of one frame with the readout of the previous frame. In Triggered mode or Triggered Dual Video mode, the exposure time and read-out time do not overlap, so the total read-out time is the sum of the exposure and read-out times.

4.4.3.1 AOI Frame Rate Examples

The Tables below describe frame rates for various AOIs using CoaXPress output. The CoaXPress interface hardware and drivers speed will affect results, so your results may vary. The camera calculates and displays the actual frame rate at any horizontal and vertical window selection.

The following tables provide examples of frame rate performance by camera within selected AOIs for 12-bit, 10-bit, and 8-bit digitization:

C4080

Camera Frame Rates	12-Bit	10-Bit	8-Bit
3840 x 2160	43.3	89.1	96.1
1920 x 1080	81.4	180.8	180.8
1280 x 720	115.4	256.1	256.1

Table 7: CXP C4080 camera example frame rates by AOI.

C2880

Camera Frame Rates	12-Bit	10-Bit	8-Bit
1920 x 1080	83.5	274	299
1280 x 720	118.2	389	423

Table 8: CXP C2880 camera example frame rates by AOI.

4.5 Subsampling

4.5.1 Pixel Averaging

The principal objective of pixel averaging is to reduce the image resolution with better final image quality than using a subsampling function. Pixel averaging reduces the output resolution by averaging several pixels together and has the advantage of reducing aliasing and reducing noise, which increases the signal-to-noise ratio (SNR). Subsampling — as opposed to averaging — has the advantage of increasing the output frame rate by reducing the number of rows read out, but also introduces aliasing in the final image. Subsampling, however, increases the output frame rate more than pixel averaging.

You cannot apply both averaging and subsampling decimation simultaneously to gain improvements both in frame rate and in SNR while minimizing aliasing. The camera offers a 4:1 (four into one) and a 9:1 (nine into one) averaging function, compatible with both monochrome and color (Bayer) cameras. Averaging four pixels together reduces the temporal noise and increases sensitivity by a factor of 2. Averaging 9 pixels together reduces the noise by a factor of 3.

The following graphic illustrates the concept of 4:1 averaging for a monochrome image sensor. The camera sums the values of pixels P1, P2, P3 and P4 and then divides the sum by four to achieve an average of the four adjacent pixels.
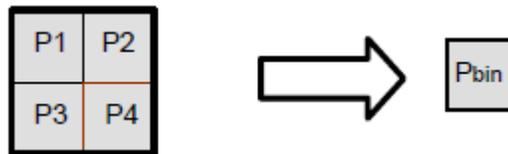

Figure 34: Monochrome pixel averaging.

Color pixel averaging works in a similar manner, but the camera aggregates like-color pixels to maintain the Bayer pattern and to allow the use of standard Bayer interpolation

color processing algorithms. With four into one color pixel averaging, the camera aggregates red pixels (R1, R2, R3 and R4) and divides the results by four to create an average red pixel value (Figure 35). Likewise, the camera sums Green pixels (GR1, GR2, GR3, and GR4) and divides the sum by four to generate the green pixel in the red-green pixel row. The camera processes Green pixels in the blue-green row similarly, along with the Blue pixels. The results of these operations preserve the Bayer pattern while averaging like color pixels to reduce the output resolution while increasing SNR.
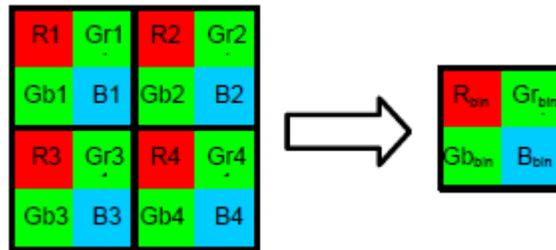
Figure 35: Principle of 4:1 averaging for Bayer color filter pattern.

The principle of 9:1 averaging function is identical to 4:1 with a 3x3 pixel area averaged together for black and white and a 9x9 pixel area averaged for the Bayer color pattern.

The averaging feature is usable on the full resolution image or within any area of interest. For example, if the area of interest is defined as quad full HD (3840 x 2160) and 4:1 averaging is selected, the output is 1080P (1920 x 1080)

4.5.2 Subsampling Decimation

Subsampling reduces the number of pixels output by reducing the output frame size but maintains the full field of view. If applied to an area of interest (AOI), the camera also maintains the field of view.

Cheetah cameras provide a flexible subsampling capability. You define the number of sequential pixels to read out (N) and the total number of pixels of the contiguous area (pixels readout + pixels skipped) (M). The subsampling decimation factors (N and M) apply along both rows and columns as shown (Figure 36 and Figure 37). The camera adjusts AOI size depending on subsampling factor, averaging factor, and the presence of a color filter array on the image sensor.

Subsampling constraints
- The N (number of contiguous pixels read out) and M (number of pixels in the area, which includes pixels read out and pixels skipped) parameters are restricted to even values.
- M must always be greater than N, and the maximum value of M is 32.
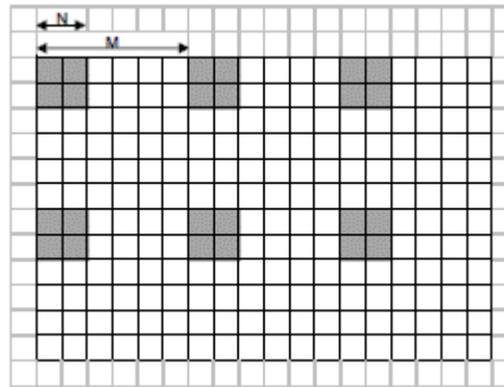
Figure 36: Monochrome subsampling with N = 2 and M = 6.
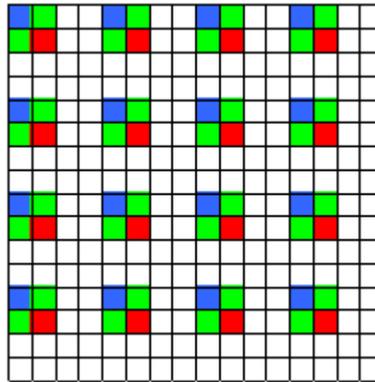
Figure 37: Color subsampling with N = 2 and M = 4.

4.6 Exposure Control

4.6.1 Internal Exposure Control, Electronic Shutter

In rolling shutter mode, each line is reset (cleared of signal) sequentially (one after another). The delay between the time that a line is reset and the time when this line is read out is the exposure time. While rolling shutter mode offers superior noise performance (and thus better sensitivity) as compared to global shutter mode, in rolling shutter mode each line of the image is captured at a slightly different time and this can introduce image artifacts when the camera or the object is moving.

In global shutter mode, all pixels in the array are reset at the same time, allowed to collect signal during the exposure time and then readout sequentially. In this way, all pixels capture the image during the same time period reducing any image artifacts due to motion within the scene or the camera.

In free-running mode for both global and rolling shutter modes, the exposure time overlaps the camera readout and is positioned to occur at the end of the frame readout. The internal exposure control timer controls the exposure and is organized into two counters: a line counter and a partial-line (sub-line) counter. In free-running mode, frames

are readout one after another so the maximum exposure time is equal to the frame time. With no frame period control (Fixed Frame Period disabled), there are 1146 lines per frame in the C2880 camera (2292 rows) and 1568 lines per frame in the C4080 camera (3136 rows). Increasing the frame period using the Fixed Frame Period control, adds additional lines (vertical blanking) to the frame readout thereby increasing the frame period and increasing the maximum exposure time.

The exposure time can be computed by first converting the contents of the Integration Lines counter and Integration Clocks (partial line) counter to time using the following Frame A exposure time equation. (Frame B is the same, save the register addresses have different values)

1) Exposure Time = (Integration Lines Counter [e.g., Reg 0728] x Line Time [e.g., Reg 0710]) + (Integration Clocks (Partial Line) Counter [e.g., Reg 072C] x 6.25 nS) [Note: all register values must be converted from hex to decimal] (Recall, one line is defined to be two rows of the image sensor)

2) Line Time:
   The line time can be computed in one of two ways:
   A) Reading the contents of Line Time register (Reg: 0710 for Frame A or Reg 0714 for Frame B), converting the hex number to decimal and multiplying by 6.25nS
   B) Measuring the frame time (GUI monitor screen) in free running mode with the fixed frame period disabled and dividing by 1146 lines per frame if using the C2880 camera or 1568 if using the C4080 camera.

   The minimum exposure in global shutter mode is 5 microseconds and 1 microsecond in rolling shutter mode.

The exposure time cannot exceed the frame time. To increase the exposure time, first increase the frame period to the maximum desired exposure time and then adjust the exposure time.

In free-running (non-triggered) operation, the camera overlaps the exposure and readout times for both global and rolling shutter modes as shown in the following figures. Both figures show an 8.33 millisecond exposure time overlapping with the 13.8 millisecond readout time. The third figure shows non-overlap exposure and readout in using a trigger.
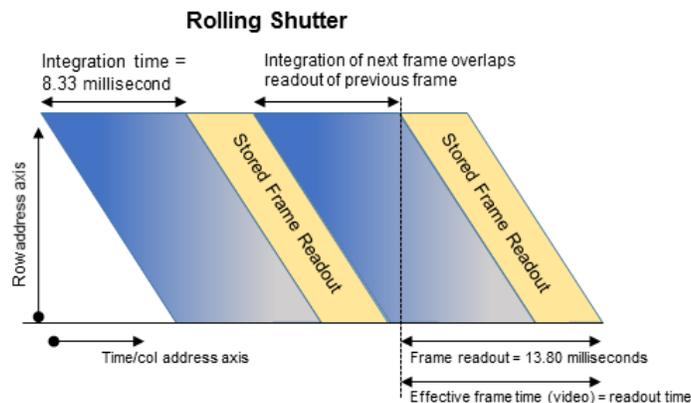
Figure 38: Rolling Shutter with 8.33 ms exposure time.

Global Shutter

Integration time = 8.33 millisecond

Integration of next frame overlaps readout of previous frame

Row address axis

Stored Frame Readout

Stored Frame Readout

Time/col address axis

Frame readout = 13.80 milliseconds

Effective frame time (video) = readout time
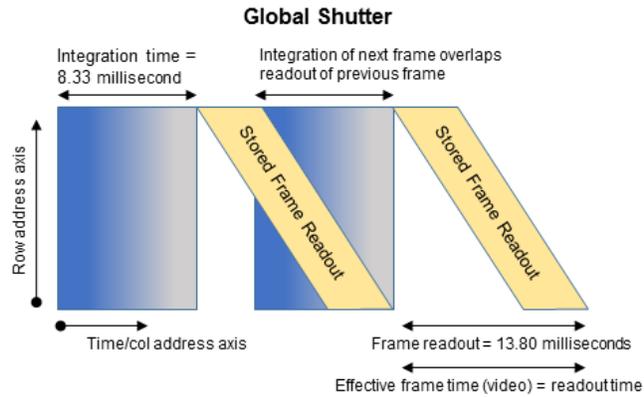
Figure 39: Global shutter with 8.33 ms exposure time.

With an external trigger, exposure times and read-out times do not overlap, and the effective frame time is the sum of both values.

Integration Time: Frame n

Stored Frame Readout

Readout: Frame n

Effective frame time = Integration time + Readout time
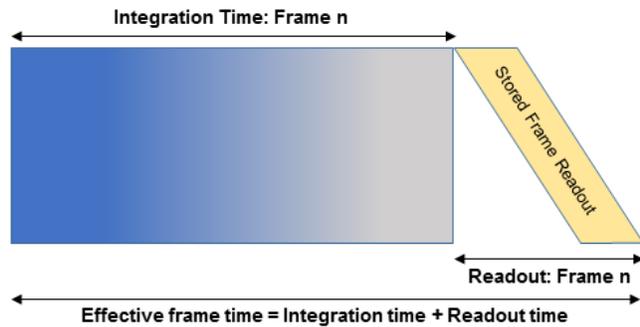
Figure 40: Global shutter with a long exposure time (integration time).

4.6.2 External Exposure Control

When using the external trigger (whether with the internal exposure timer or with trigger pulse width), the exposure and readout are not overlapped.

When using the internal exposure timer and external trigger, the following sequence occurs:

1. The camera waits for the trigger signal.
2. Upon trigger, there is a delay of ~45 microseconds plus 1 to 2 line times.
3. Then the exposure time begins followed by readout.
4. The camera then idles and awaits the next trigger.

The camera can control exposure using an external pulse; the pulse duration determines the exposure. In global shutter mode, the minimum exposure time is about 6 microseconds. In rolling shutter mode, the minimum exposure time is equal to the frame time, because the exposure must occur during the read-out time. Refer to 4.7 CoaXPress Trigger Inputs and 4.13 I/O Control.

4.6.3 Programmable Line and Frame Time

The C4080 and C2880 cameras provide high data rates that can overrun the bandwidth of the CoaXPress and output interface. To prevent this overrun, the variable frame time control provides the ability to run the camera in full resolution at a frame rate slower than the nominal frame read-out rate. Frame time control adds a delay after the readout of each line and at the end of the frame. It reduces the overall output frame rate to match the camera frame rate to each application-specific requirement. You should add only enough delay to the camera line time to match the CoaXPress data capture rate. Adding more line delay will decrease overall camera performance by increasing dark current within the image.

CAUTION ⚠️

If the frame time is greater than 50ms, keep the camera still to prevent motion smear from appearing on the image.

4.7 CoaXPress Trigger Inputs

In the normal mode of operation, the camera is free running and continually reading out the sensor. In contrast, Trigger mode allows you to synchronize the camera to an external timing pulse. Trigger inputs can control the exposure times of Frame A and Frame B or Dual Video mode switching. In Dual Video mode, enabling the trigger input causes the camera to output a user-defined number of Frame A followed by a user-defined number of Frame B; the camera outputs Frame A until the trigger is received and then outputs a user-defined number of Frame B.

The camera provides three input modes for external triggering: software, internal (pulse generator), and external. Note that the trigger input requires mapping to a corresponding camera input (4.13 I/O Control)

- **External** – camera receives the trigger signal coming from the connector located on the back of the camera.
- **Software** – camera expects a single trigger (one clock cycle) generated by the computer. You can trigger the camera by sending the GenICam™ trigger software command.
- **Internal** – camera receives the trigger signal from the internal pulse generator.

4.7.1 Acquisition and Exposure Control

For each trigger input, you can set the trigger edge and de-bounce (de-glitch) time.

- **Triggering Edge** – select one of the following to activate triggering edge:
    - o **Rising** – uses the rising edge for triggering
    - o **Falling** – uses the falling edge for triggering
- **De-bounce** – de-bouncing trigger inputs prevents multiple triggering from ringing triggering pulses. De-bounce provides eight choices of de-bounce intervals:
    - o **Off** – no de-bounce (default)
    - o **10** μs, **50** μs, **100** μs, **500** μs de-bounce interval
    - o **1.0**ms, **5.0** ms, **10.0** ms de-bounce interval
- **Exposure Time** – set the exposure for all frames using either of the following:
    - o **Pulse Width** – the trigger pulse width (duration) determines the exposure, subject to limitations. In Global Shutter mode, the minimum exposure is about 6 microseconds. In Rolling Shutter mode, the minimum exposure is equal to the minimum frame time.
    - o **Internal** – the camera internal exposure register determines the exposure.

CAUTION ⚠️

You must set the de-bounce interval smaller than the trigger pulse duration. Adjust the interval accordingly. With triggering enabled, programmable integration is not active.

4.7.2 Triggering Modes

A. Exposure Control:

With trigger mode enabled, the trigger can control the integration time of Frame A and/or Frame B using the Exposure Control Trigger Pulse Width control. The trigger can switch between Frame A and Frame B in Dual Video Trigger mode. The Exposure Control Trigger Pulse Width option is available only after selecting single video (either Frame A or Frame B). Control of the exposure using the trigger pulse width is not available in Dual Video or Dual Video Trigger modes.

Global Shutter Mode (GS):

When the trigger pulse width controls the exposure time in GS mode, the camera idles and waits for a trigger signal. Upon receiving the trigger signal, the camera starts integration for the frame, completes the integration, and reads out the image. A small delay occurs between the trigger active edge and the exposure start. You can set the exposure time manually using the internal exposure register setting or by using the duration of the trigger pulse. The minimum exposure time using the trigger pulse width is two microseconds. Upon completing the readout, the trigger cycle is completed and the camera idles awaiting the next trigger pulse.

Rolling Shutter Mode (RS):

With limitations, trigger pulse width can control exposure time. In this case, the minimum exposure time is equal to the time required to reset all the lines within the image sensor (the time necessary to read out one frame of the image sensor). In other words, the

minimum exposure time is equal to the frame time. Longer exposure times are possible, but the camera does not support exposures shorter than one frame time.

Upon receiving the active edge of the trigger signal, the camera resets image sensor line #1 and starts the exposure of line #1. One line-time later, line #2 resets and the integration of line #2 begins. Each line is reset one line-time after the prior line, and this process continues until the entire image sensor resets. When the trigger signal goes inactive (a minimum of one frame-time later), the integration concludes for the first line and the image sensor reads out one line at a time. The time between trigger pulses (start of exposure) must be at least the exposure time plus the read-out time of the image sensor.

It is possible to use strobe illumination in rolling shutter mode if the scene is completely dark. The strobe illumination must occur after all lines within the image sensor reset (one frame read-out time), and the exposure time must therefore be set to the sum of the image sensor read-out time plus the exposure window for the strobe. The sequence of events is as follows:

1. Exposure starts and all rows in the image sensor reset (one frame time).
2. Strobe illumination flashes.
3. Exposure ends and the readout begins.
4. After the readout completes, the next exposure can begin.

Trigger Mode -- Exposure and Readout Times:

In trigger mode, the exposure time and readout time are not overlapped and occur sequentially in time. If the period of the trigger pulse is longer than the exposure time and the readout time is combined, the camera frame rate will be the trigger rate. However, if the exposure time plus the readout time exceed the period of the trigger pulse, then the camera ignores subsequent trigger pulses until the exposure time and readout times are completed (See the following figures). After the exposure and readout times are completed, the camera accepts the next trigger pulse and the sequence repeats. Therefore, in the case where the exposure time and readout time exceed the trigger period, the frame time increases in increments of the trigger period.

For example, if the exposure time and readout time are both 20mS and the trigger period is 50mS, then the frame rate is 20Hz (1 / 0.050). If the exposure time is increased to 40mS (readout time remains 20mS), then the camera skips one trigger pulse and the frame rate is 1 / (2 x 0.050) = 10 Hz. If the exposure time increases to 90mS, then the camera skips two trigger pulses, and the frame rate is 1 / (3 x 0.050) = 6.6 fps. As you increase the exposure time, the frame period increases in increments of 50mS (the trigger period).
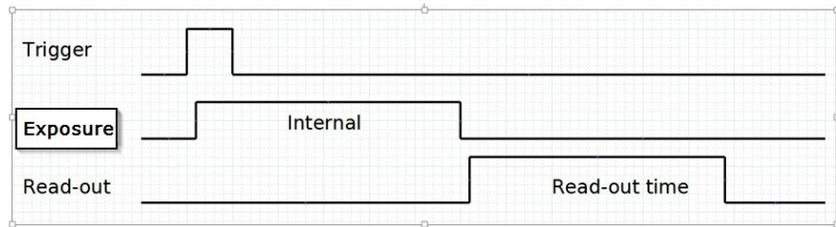
Figure 41: Standard Trigger Mode, Internal Exposure Control.
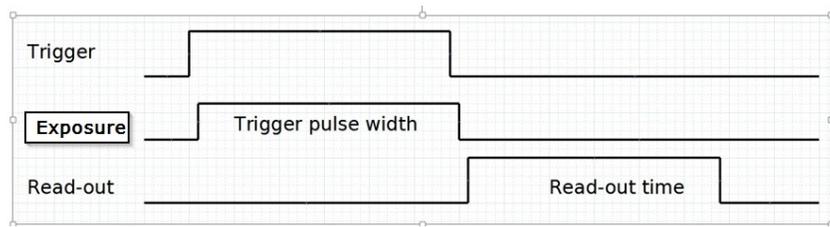
Figure 42: Standard Trigger Mode, GS Trigger Pulse Width Exposure Control.
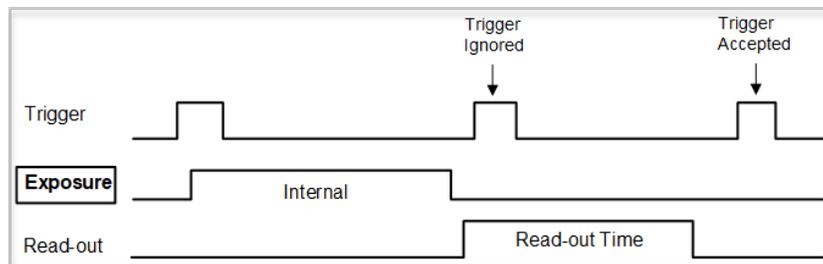
Figure 43: In Trigger Mode, exposure and readout times impact triggers.

B. Dual Video Trigger:

If the Dual Video Trigger is selected, the camera outputs Frame A continuously until the external trigger signal is received. Upon receiving the external trigger, the camera switches to Frame B and outputs N Frame B (the number of frames is user-selectable with N = 1 to 256). After outputting N Frame B, the camera reverts to Frame A and continues to output Frame A until receiving the next trigger input.

CAUTION ⚠️

The time interval between trigger pulses must be greater than the combined exposure and frame time. If the time between triggers is too short, the camera will ignore some trigger pulses.

4.8 Strobes

The camera can provide up to two strobe pulses for synchronization with an external light source, with additional cameras, or with other peripheral devices. You can set each strobes pulse duration and the delay with respect to the start of the exposure time or the start of the readout time for either Frame A, Frame B, or both. The maximum pulse duration and the maximum delay can be set up to 1 second with 1.0µs precision. You can assign the strobe pulse to an external output. Refer to Section 2.14 I/O Control.
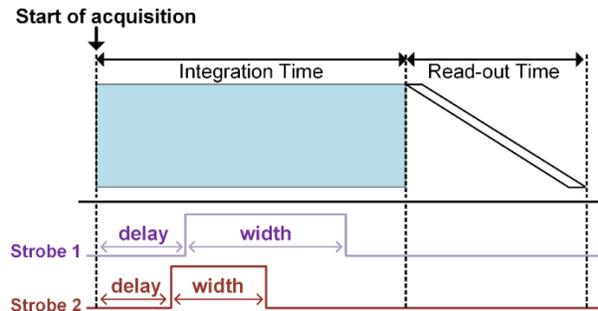
Figure 44: Strobe Positioning with Respect to Exposure Start.

4.9 Video Amplifier Gain and Offset

4.9.1 Analog Domain – Manual Control

The camera takes advantage of the analog gain functionality built into the KAC-12040 image sensor. The manufacturer recommends applying analog gain before using the digital gain function. The image sensor automatically adjusts the black level as the analog gain is adjusted to minimize fluctuation. The user-adjustable target black level is added after the gain stage, and adjustments to this setting will not affect dark level sensitivity. The gain range depends on output bit depth with gain of 1x, 2x, and 4x (12dB) possible using 12-bit digitization and gain of 1x 2x, 4x, and 8x (18dB) possible using 10-bit digitization (Table 9).

Analog Gain Codes and Steps		
Select Code	**10-Bit Gain**	**12-Bit Gain**
2	NA	4.00
4	8.00	2.00
8	4.00	1.00
10	3.20	NA
12	2.66	NA
14	2.28	NA
16	2.00	NA
18	1.77	NA
20	1.60	NA
22	1.45	NA
24	1.33	NA
26	1.23	NA
28	1.14	NA
30	1.07	NA
32	1.00	NA

Table 9: Analog gain steps.

4.9.2 Digital Domain – Manual Control

For optimal noise performance, apply analog gain before digital gain. The camera applies digital gain before the application of the user-selected target black level. The camera achieves digital gain using a combination of coarse and fine gain parameters. Fine gain enables granular adjustments to coarse gain. The camera applies digital gain on each ADC output after clamp and noise correction and before application of the user-selected target black level. First, the sensor image references to 0dn, then the camera applies digital gain in a signed number space, and finally the image shifts up to the desired black level. This provides good precision with low gains.

The sensor performs digital math at deeper bit depths than output. This minimizes quantization and histogram distortion with digital gain.

$$G = 2^i * \left(1 + \frac{f}{64} \right)$$

Figure 45: Sensor digital math.

Coarse gain defines the exponent part; fine gain defines the fractional part from 0 to 63. This format provides a gain range from x1 to x15.875 with a varying step. To provide finer control at lower gain settings, the digital gain step size varies (Table 10).

Coarse Gain Value	Fine Gain Range	Step
0	1 to 1.984375	0.015625
1	2 to 3.96875	0.03125
2	4 to 7.9375	0.0625
3	8 to 15.875	0.125

Table 10: Digital gain step sizes.

4.10.11 Wide Dynamic Range Function

4.10.1 Overview

Cheetah cameras provide an effective solution for outdoor and uncontrolled lighting applications. The camera applies wide dynamic range (WDR) (or wide dynamic range function) to each individual pixel. In wide dynamic range mode, the camera effectively varies the exposure time of each pixel based on the intensity of the source at each pixel location. For each pixel, the camera's programming enables selecting up to four user-defined exposure times based on the intensity of the source at the individual pixel. For example, you can set the following:

- Ultra-short exposure for ultra-bright pixels within the image.
- Longer exposure for very bright pixels.
- Long exposure for bright pixels while allowing dark pixels within the image to integrate for the full exposure time.

The camera determines the intensity of the source at each pixel and categorizes pixels into dark, bright, very bright, or ultra-bright based on user-defined criteria. You do not need to know which pixels are bright or dark; the camera takes care of managing these details.

Unlike some extended dynamic range schemes involving two or more separate exposures separated by one or more frame times, Cheetah cameras can provide up to four separate exposures based on the source intensity at each pixel within one exposure time, thus eliminating motion artifacts. While up to four separate exposures are possible, you can opt to use only two or three separate exposures for simplicity. You define the exposure

times and partition the camera output to collect the data for the dark, bright, very bright, and ultra-bright pixel information. In this way, the camera can capture up to four different intensity slopes in one image capture.

WDR functionality can be disabled or enabled and (Figure 47).
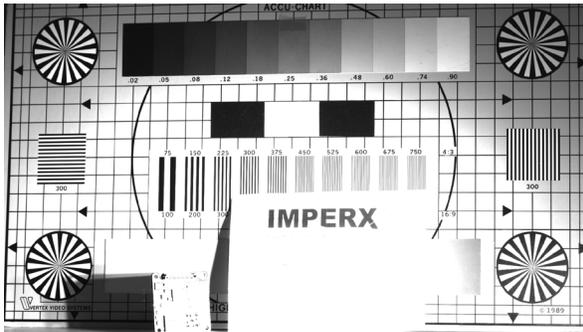
Figure 46: WDR Mode Disabled.
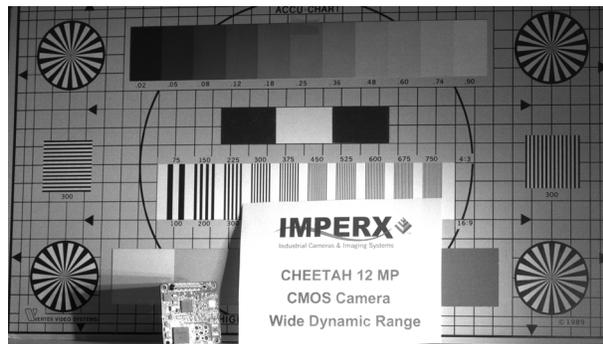
Figure 47: WDR Mode Enabled.

To extend the dynamic range of the camera, you can partition the output into several user-defined zones. In the simplest case, you can partition the output into one region for dark pixel data where pixels integrate for the full exposure time and another region for bright pixel data where pixels integrate for only a small portion of the total exposure time (Table 11).

Assuming 10-bit digitization, dark pixel data values range from 0 to 512 counts (50% of the output) and bright pixel data values range from 513 to 1024 counts (51% to 100% of the output). Keep in mind that the camera captures bright pixel data with a much shorter exposure time. For example, suppose you select a bright pixel exposure time that is 10% of the overall exposure time. In this case, a pixel with a value of 612 counts resides in the bright pixel data partition and represents 100 counts (612 – 512) taken with an exposure that is 10% of the total exposure. The camera collects these 100 counts of signal with $1/10^{th}$ of the exposure time of the dark pixels. Therefore, the 100 counts are 10x brighter than 100 counts of signal collected in the dark pixel partition.

Percent of Output	Pixel Data
100%	
	Bright Pixel Data
51%	
50%	
	Dark Pixel Data
0%	

Table 11: Example of output partitioning for two intensity slopes.

To reinforce the concept of output partitioning, suppose you select the partitioning in Table 12 with 10-bit digitization and select the total exposure to be 50ms (dark pixels), the Bright pixel exposure to be 5ms, the Very Bright pixel exposure to be 0.5ms, and the Ultra-Bright pixel exposure to be 0.05ms. In this example, Dark pixels with a 50ms exposure are contained between 0 and 300 output counts (30% of output), Bright pixel data with a 5ms exposure have counts between 301 and 600, Very Bright pixel data with 0.5ms exposures have counts between 601 and 800, and Ultra Bright pixel data with 0.05ms exposures have counts between 800 and 1000. A single count in the Ultra Bright pixel data region represents a signal that is 1,000x higher in intensity (50ms / 0.05ms) than a single count in the Dark pixel data region.

Percent of Output	Pixel Data
100%	Ultra Bright Pixel Data
81%	
80%	Very Bright Pixel Data
61%	
60%	Bright Pixel Data
31%	
30%	Dark Pixel Data
0%	

Table 12: Example of output data partitioning for intensity slopes.

As another example of the range of exposures possibilities, you could set the exposure time for the pixels in the darkest region of the image at 33.0 milliseconds, consistent with a 30 frame per second video rate. For Bright pixels within the scene, you could select an exposure time of 3 milliseconds, and for Very Bright pixels, select an exposure time of 300 microseconds. The output will partition into three zones: one for Dark pixel exposure data, one for Bright pixel exposure data, and one for Very Bright pixel exposure data.

It is useful to set the wide dynamic range parameters using ratios. The overall entire exposure period (Texp) is the time during which the dark pixels integrate to some value.

As an example, describe this time period as the quantity X and specify that 40% of the output range is allocated to Dark pixel data. You might then set the exposure time for Bright pixels to 5% of the overall exposure time (Bright pixel exposure is 0.05X) and allocate 35% of the remaining output to these bright pixels. Finally, for the Very Bright pixels within the scene, you might set the exposure time to 0.5% of the overall exposure (Very Bright pixel exposure is 0.0025X). The camera allocates the remaining portion of the output (25%) to these Very Bright pixels. In this way, the camera can support three separate exposure times.

The following example (Figure 48) compares a single slope (normal CCD or CMOS camera) exposure with a dual slope exposure in which Dark pixels integrate for the full exposure time up to 30% of the camera output while Bright pixels integrate for only 10% of the exposure time with 70% of the camera output partitioned to Bright pixel information.

Dual Slope Vs. Single Slope Integrations
Bright pixels integrate for 10% of exposure using 70% of the output
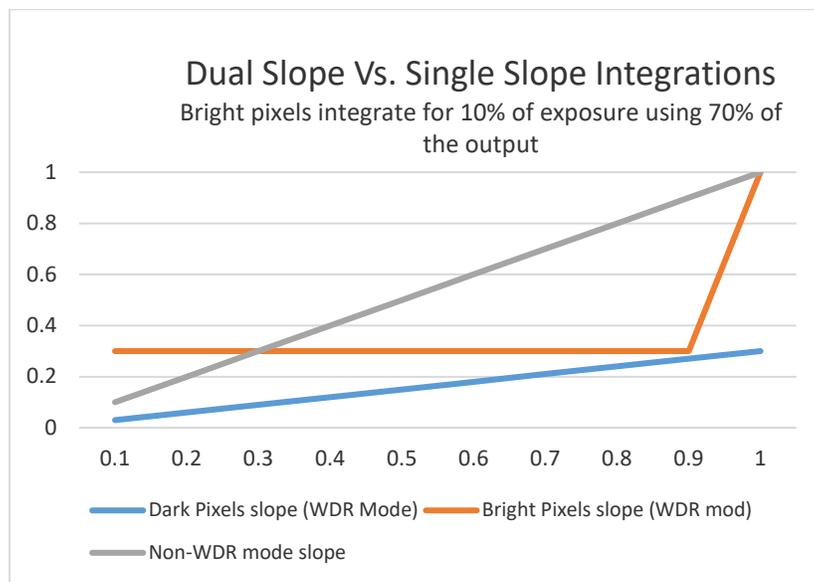
Figure 48: Dual Slop vs Single Slope Integration.

You can translate pixel data back to linear space by accounting for the different exposure times in each of the output partitions. For example, suppose Bright pixel data is contained between 301 and 1000 of the camera output counts (10-bit system). By subtracting 300 from every pixel with a value greater than 300 counts and multiplying the result by the ratio of the Total Exposure (Texp) period divided by the Bright pixel exposure time, the Bright pixel data can be properly referenced to the Dark pixel data:

Bright pixel (Linear) =   (Bright pixel counts– Dark pixel max counts) x (Texp / Bright pixel exposure time)

Another way to view the data partitioning concept is to view the histogram of the output data (Figure 49). The histogram shows four output partitions. Bear in mind that each data region (Dark, Bright, Very Bright, and Ultra Bright) has a different exposure time.

Wide Dynamic Range (WDR) – Histogram View
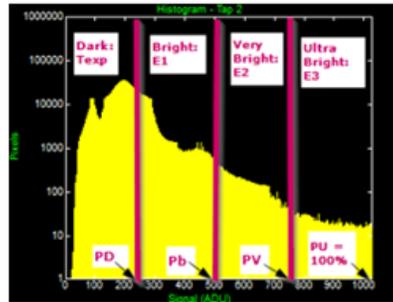
Dark Pixel Data
- Exposure time = Texp
- Between 0 counts and PD

Bright Pixel Data
- Exposure time = Tb (Texp – E1 in GUI)
- Between PD and Pb (250 to 500)

Very Bright Pixel Data
- Exposure time = TV (Texp – E2 in GUI)
- Between Pb and Pv (500 to 750)

Ultra Bright Pixel Data
- Exposure time – TU (Texp – E3 in GUI)
- Between Pv and Pu (750 to 1,000)

Percentage (of output) Dark (PD) set to 25% (P1 in GUI)
Percentage (of output) Bright (Pb) set to 50% (P2 in GUI)
Percentage (of output) Very Bright (Pv) set to 75% (P3 in GUI)
Percentage (of output) Ultra Bright (Pu) set to 100%

Figure 49: Output Partitioning Using a Histogram.

4.10.2 Wide Dynamic Range Controls

The wide dynamic range (WDR) function is available only in global shutter mode. You have the option of enabling or disabling wide dynamic range. When disabled, all pixels within the array integrate charge for the full exposure time as defined by the exposure control settings. After activating WDR, the exposure time for each pixel varies based on the following user-defined settings:

Dark Pixels: The normal camera exposure controls set the exposure time, and dark pixels integrate for the full exposure period (Texp) as if WDR mode is disabled. The amount of the camera output allocated to dark pixels is set by parameter P1, and dark pixel data is contained between 0% of camera output to the P1 percentage level. P1 can range from 15% of the camera output to 100% (Table 13). If P1 is set to 100%, the entire output is allocated to Dark Pixels and WDR is effectively disabled.

Table 13: Camera Output Allocation (%).

Bright Pixels: The exposure time for bright pixels is set by parameter E1. The Bright pixel exposure time is defined as the Total Exposure Period (Texp) minus E1. For example, if Texp (Dark Pixel Exposure time) is 50ms and you want to set the Bright pixel exposure time to 5ms, then you must set E1 to 45ms (50ms – 45ms = 5ms).

$$\text{Tb (Bright)} = \text{Texp} - \text{E1}$$

E1 is a value in microseconds and must be some fraction of the overall exposure time (usually 90% of Texp or more). The minimum value for E1 is 2 microseconds. Bright pixel data is partitioned between the P1 and P2 output settings. Like P1, parameter P2 can have values ranging from 15% to 100% of the camera output (16 steps) and <u>must be</u> greater than P1. If P2 is set to 100%, then the camera output is partitioned into two zones: Dark Pixel data (0% to P1) and Bright pixel data (P1 to 100%).

Very Bright Pixels: The exposure time for the Very Bright pixels is set by parameter E2. The Very Bright pixel exposure time is defined as the Total Exposure Period (Texp) minus E2. For example, if Texp (Dark Pixel Exposure time) is 50.0ms and it is desired to set the Very Bright pixel exposure time to 0.5ms, then E2 must be set to 49.5ms. (50.0ms – 49.5ms = 0.5ms).

$$Tvb \text{ (Very Bright)} = Texp - E2$$

E2 is a value in microseconds and must have a value between the E1 exposure time and Texp. The minimum E2 value is 2 microseconds. The amount of camera output allocated to Very Bright pixels is set by parameter P3, which can have values ranging from 15% to 100% of the camera output (16 steps) and must be greater than P2. The Very Bright pixel data is contained between the P2 percentage of output and the P3 percentage of output. If P3 is set to 100%, then the camera output is partitioned into three zones.

Ultra Bright Pixels: The exposure time for the Ultra Bright pixels is set by parameter E3. The Ultra Bright pixel exposure time is defined as the Total Exposure Period (Texp) minus E3. For example, if Texp (Dark Pixel Exposure time) is 50.00ms and it is desired to set the Ultra Bright Pixel exposure time to 0.05ms, then E3 must be set to 49.95ms. (50.00ms – 49.95ms = 0.05ms).

$$Tub \text{ (Ultra-Bright)} = Texp - E3$$

E3 is a value in microseconds and must have a value larger than E2, but less than Texp. The minimum E3 value is 2 microseconds. The amount of camera output allocated to Ultra Bright pixels is between the P3 setting and 100% of the camera output.

The following graphics provide a single knee point demonstration of the WDR function (Figure 50). It is useful to note how the output histogram changes as P1 is varied from 75% to 50% to 25%.

Wide Dynamic Range (WDR) Using the Histogram (1 knee point)
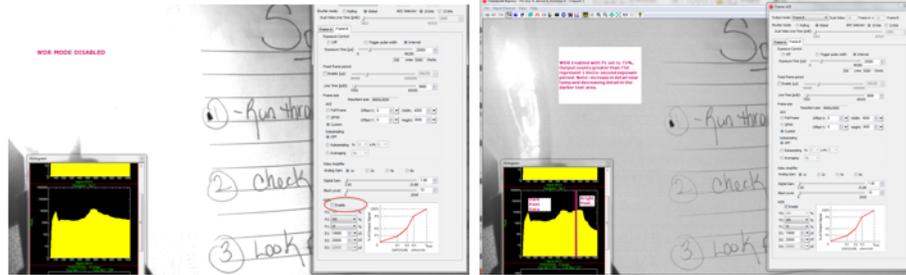
WDR Disabled. The output represents the 'normal' Dynamic Range. All output counts were exposed for full 20mS exposure time.

PD (P1) Set to 75%, Counts greater than 750 received a 1 micro-second exposure, Counts below 750 received full 20mS exposure.
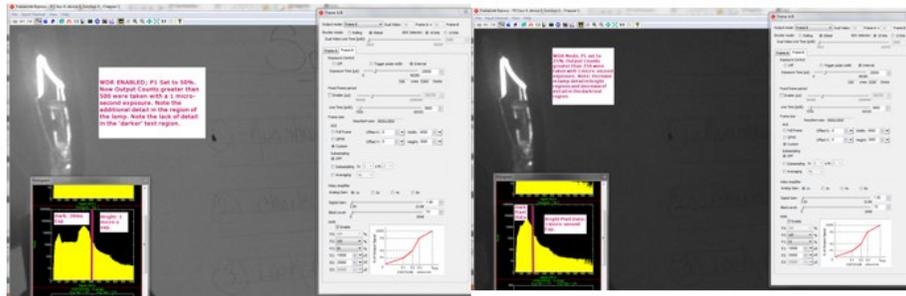
Pd (P1 in GUI) is set to 50%; Output counts greater than 500 were exposed for 1 micro-second.
Note: more detail in lamp region and less contrast in dark.

Pd (P1) is set to 25%, Output counts greater than 250 were exposed for 1 micro-second.

Figure 50: A Single Knee Point Demonstrations of the WDR Function.

4.10.3 Initial WDR Setup Recommendations

For initial Wide Dynamic Range (WDR) setup, the scenario below provides one knee point to get a usable image. It also allows experimentation with various settings.

1. Set the overall exposure time so the dark portions of the image are visible with good contrast while other portions of the image are overexposed with no visible detail.
2. Set E1 to 90% (or 95%) of the overall exposure time.
3. Set P1 to 50% then set P2 and P3 to 100%.
4. Try varying P1 and E1 and observe the impact on the image (and histogram).

Increasing P1 increases the amount of contrast in the dark regions of the image while decreasing contrast in the bright regions. If the dark regions appear noisy or if the color reproduction in the dark regions is poor, try increasing P1. Changing E1 changes the exposure time for the bright areas. For more contrast, try increasing P1. View a histogram of the output to get a sense of how changes in P1 affect the output.

In a scene with several different intensity levels, two knee points can be helpful. If two knee points (3 intensity slopes) are required, then both E1 and E2 (E1 is the exposure time for bright pixels and E2 is the exposure time for the Very Bright pixels.) must be used. Below is an initial setting for applications that have several areas of varying intensities.

1. Set the overall camera exposure time so areas in the darkest regions of the image have contrast and bright areas are overexposed.
2. Set Texp - E1 to 10% of the overall exposure time and set Texp - E2 to 1% of the overall exposure time.
3. Set P1 to 40%, P2 to 70%, and P3 to 100%.

Compressing the bright areas of the image into the camera's output range will make wide dynamic range images look flat and dark. The histogram of the output is useful for seeing the impact of changes to P1, P2, and P3 settings. The LUT function can stretch the image and increase the image brightness, if needed, keeping in mind that data is not linear and is partitioned into different exposure ranges.

4.10.4 WDR at Maximum Frame Rates

To provide the highest frame rates, the exposure time and read-out time overlap; this means that while Frame 1 is being read out, Frame 2 is being exposed. The exposure time for Frame 2 is always positioned at the end of the Frame 1 and any additional WDR exposures (E1, E2, and E3) are positioned at the end of the overall exposure time.

When the application demands maximum frame rate, the exposure time of Frame 2 overlaps with the readout of Frame 1 (for lower frame rate applications, the exposure for Frame 2 will occur after Frame 1 is read out (non-overlapping)). An image artifact (a faint horizontal line) might appear at the beginning of the WDR (E1, E2, and E3) exposures <u>if</u> the WDR exposures for Frame 2 overlap with the Frame 1 read-out time. At maximum frame rate, these artifacts typically occur very near the bottom of the image.

For example, suppose the camera is providing a system-constrained maximum frame rate of 50 fps (20,000 microsecond frame time). Also, suppose the exposure time (Texp) is 5,000 microseconds and two additional WDR exposures (E1 and E2) are used. E1 is set to 4,000 microseconds (a WDR exposure of 1,000 microseconds) and E2 is set to 4,900

microseconds (a 2nd WDR exposure of 100 microseconds). Assume a full 4000 x 3000 resolution image is read out from the C4080 camera and Frame 1 begins reading out at time equals 0 seconds. In this example, the exposure for Frame 2 begins 15,000 microseconds after Frame 1 readout begins (5,000 microseconds before the end of the Frame 1 read-out time) and the first WDR exposure (E1) begins 1,000 microseconds before the end of Frame 1 readout. Finally, the 2nd WDR exposure (E2) begins 100 microseconds before the end of the Frame 1 readout. In this example, two-line artifacts might appear. These artifacts will be located where they occurred with respect to the readout of Frame 1 in time. For the E1 exposure, the artifact may be seen at image line 150 (1000 microseconds before the end of the frame readout) and, for the E2 exposure, an artifact at line 15 (100 microseconds before the end of the Frame 1 readout) might appear. If the E1 and E2 exposures do not overlap with the readout of Frame 1, no artifacts will appear.

To eliminate these artifacts when trying to achieve maximum frame rates:
- Enable the Fixed Frame Period control to increase the frame time slightly so the WDR exposures occur after the frame readout ends. For example, if the minimum frame time is 20ms (50 fps) and the longest WDR exposure desired is 2ms (so the WDR exposure occurs 2ms before the end of the frame time), use the Fixed Frame Period control to increase the frame time by 2ms to 22ms.
- Use trigger mode. In this mode, exposure and readout do not overlap, hence, WDR image artifacts do not occur.

4.11 Data Output Format

4.11.1 Bit Depth

You can vary the internal digitization level within the image sensor to improve frame rate. A 10-bit digitization level allows the analog-to-digital converter (ACD) to settle more quickly, enabling higher frame rates while 12-bit digitization levels provide higher dynamic range at the expense of frame rate. The camera can output the data in 12, 10, or 8-bit format. In 8-bit output, a standard bit reduction process is used and the least significant bits are truncated.

12-bit digitization (Table 14)
- If the camera is set to output 12-bit data, the image sensor data bits map to D0 (LSB) to D11 (MSB) output bits.
- If the camera is set to output 10-bit data, the image sensor most significant data bits [D2 to D11] map to the D0 (LSB) to D9 (MSB) output bits.
- If the camera is set to output 8-bit data, the image sensor most significant data bits [D4 to D11] map to D0 (LSB) to D7 (MSB).

MSB   **Internal Camera - 12 bits**   **LSB**

D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
P11	P10	P9	P8	P7	P6	P5	P4	P3	P2	P1	P0

MSB   **Camera Output - 12 bits**   **LSB**

D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
P11	P10	P9	P8	P7	P6	P5	P4	P3	P2	P1	P0

MSB   **Camera Output - 10 bits**   **LSB**

D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
P11	P10	P9	P8	P7	P6	P5	P4	P3	P2

MSB   **Camera Output - 8 bits**   **LSB**

D7	D6	D5	D4	D3	D2	D1	D0
P11	P10	P9	P8	P7	P6	P5	P4

Table 14: 12-bit Internal Digitization with 8, 10, 12-bit Outputs.

10-bit digitization (Table 15)

- If the camera is set to output 12-bit data, the image sensor data bits are mapped to the D2 (LSB) to D11 (MSB) output bits and output bits D0 and D1 are set to zero.
- If the camera is set to output 10-bit data, the image sensor data bits are mapped directly to D0 (LSB) to D9 (MSB).
- If the camera is set to output 8-bit data, the image sensor data most significant data bits (D2 to D9) map to D0 (LSB) to D7 (MSB).

MSB   **Internal Camera - 12 bits**   **LSB**

D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
P9	P8	P7	P6	P5	P4	P3	P2	P1	P0

MSB   **Camera Output - 12 bits**   **LSB**

D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
P9	P8	P7	P6	P5	P4	P3	P2	P1	P0	0	0

MSB   **Camera Output - 10 bits**   **LSB**

D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
P9	P8	P7	P6	P5	P4	P3	P2	P1	P0

MSB   **Camera Output - 8 bits**   **LSB**

D7	D6	D5	D4	D3	D2	D1	D0
P9	P8	P7	P6	P5	P4	P3	P2

Table 15: 10-bit Internal Digitization with 8, 10, and 12-bit Outputs.

4.12 Pulse Generator

The camera has a built-in pulse generator. You can program the camera to generate a discrete sequence of pulses or a continuous trail (Figure 51). You can use pulse generator as a trigger signal or map it to one of the outputs (refer to I/O Control section). The discrete number of pulses can be set from 1 to 65535 with a step of 1. You can set the following options:

- **Granularity** – Indicates the number of clock cycles used for each increment of the width and the period. Four possible options are available (x1, x10, x100, and x1000).
- **Period –** Indicates the amount of time (also determined by the granularity) between consecutive pulses. Minimum value is 1, maximum is 1,048,575.
- **Width –** Specifies the amount of time (determined by the granularity) that the pulse remains at a high level before falling to a low level. Values range from a minimum 1 to maximum 524,287.
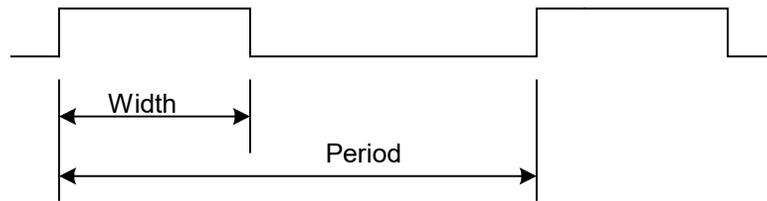

Figure 51: Internal Pulse Generator.

4.13 I/O Control

4.13.1 Input / Output Mapping

The camera has two external inputs (1 TTL input and 1 opto-coupled input) and two external outputs wired to the 12-pin HIROSE connector located on the back of the camera. You can map the camera outputs to Trigger, Pulse Generator, Strobe One, or Strobe Two. For each mapped signal, you can select either active High or active Low. The following tables show all possible mapping options for camera inputs and outputs (Table 16) (Table 17).

Input Signal	IN1	IN2
Trigger	✓	✓

Table 16: CHEETAH input mapping.

Output Signals	OUT1	OUT2
Trigger	✓	✓
Pulse Generator	✓	✓
Strobe One	✓	✓
Strobe Two	✓	✓

Table 17: CHEETAH output mapping.

4.13.2 Electrical Connectivity

The Cheetah has two external inputs: IN 1 and IN 2. Input IN 1 is optically isolated, while Input IN 2 accepts Low Voltage TTL (LVTTL). Cheetah provides two general-purpose outputs; OUT 1 is a 5v TTL (5.0 Volts) compatible signal and OUT 2 is opto-isolated.

A. Input IN 1- Opto-Isolated

The input signal IN 1 and IN 1 Rtn are optically isolated, and the voltage difference between the two must be positive between 3.3 and 24 volts (Figure 52).
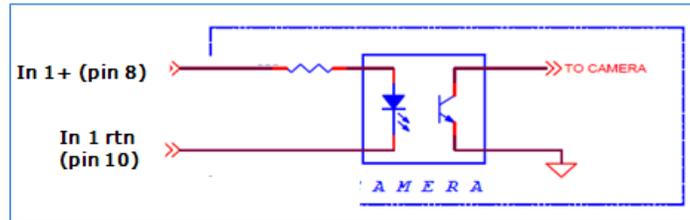

Figure 52: IN 1 Electrical Connection.

B. Input IN 2 LVTTL

The input signals IN 2 and IN 2 Rtn provide an interface to a TTL or LVTTL input signal (Figure 53). The signal level (voltage difference between the inputs IN 2 and IN 2 Rtn) must be LVTTL (3.3 volts) or TTL (5.0 volts). The total maximum input current must not exceed 2.0 mA.
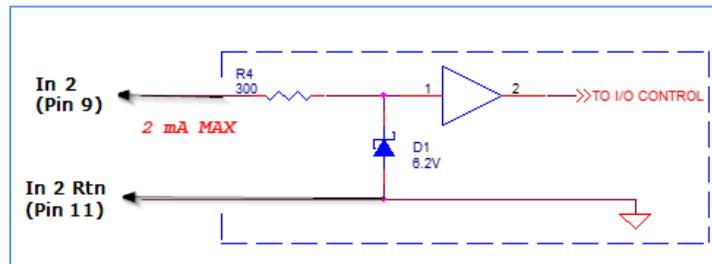

Figure 53: IN 2 Electrical Connection.

C. Output OUT 1 LVTTL

Output OUT 1 is a 5v TTL (5.0 Volts) compatible signal and the maximum output current must not exceed 8 mA (Figure 54).
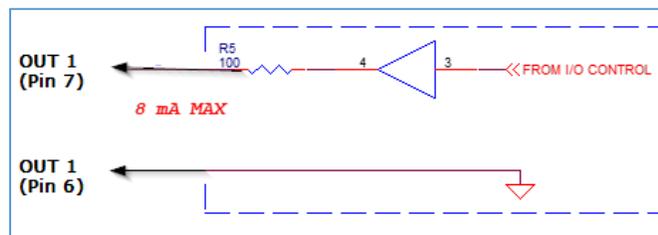

Figure 54: OUT 1 LVTTL Electrical Connection.

D. Output OUT 2 – Solid state relay, optically isolated

Output OUT2 is an optically isolated switch. There is no pull-up voltage on either contact. External pull-up voltage of up to 25 volts is required for operation. Output is not polarity sensitive. AC or DC loads are possible. The voltage across OUT2 Contact 1 and OUT2 Contact 2 must not exceed 25 volts and the current through the switch must not exceed 50 mA. On resistance is less than 5 Ohms.
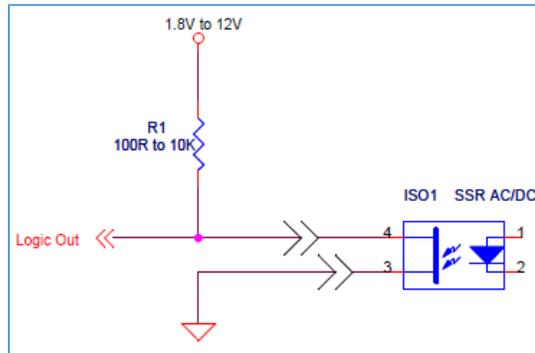
*Figure 55: Open drain logic driver.*
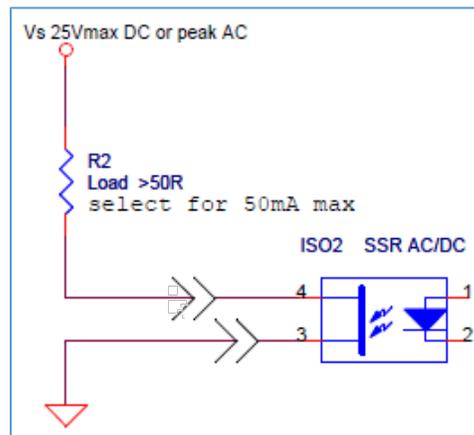
Figure 56: Low side load driver.
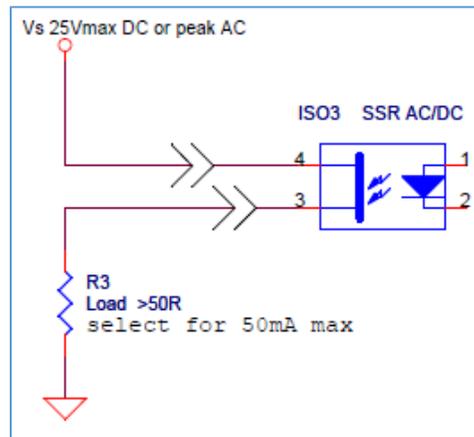
Figure 57: High side load driver.

4.14 Test Image Patterns

4.14.1 Test Image Patterns

The camera can output several test images for verifying the camera's general performance and connectivity to the CoaXPress interface. This ensures that all the major modules in the hardware are working properly and that the connection between the CoaXPress and camera is synchronized; that is, the image framing, output mode, communication rate, and so on are properly configured. Test image patterns do not exercise and verify the image sensor functionality. The following test image patterns are available:

Patterns	Description
H Ramp Still	Displays a stationary horizontal ramp image.
V Ramp Still	Displays a stationary vertical ramp image.
H Ramp Move	Displays a moving horizontal ramp image.
V Ramp Move	Displays a moving vertical ramp image.
Cross-hairs	Displays cross-hair pattern in center of image over a superimposed live image (cross-hair thickness is 2 pixels).

Table 18: Test patterns.

4.15 White Balance and Color Conversion

4.15.1 White Balance Correction

The color representation in the image depends on the color temperature of the light source. Cheetah cameras have a built-in algorithm to compensate for this effect. With white balance correction enabled, the camera collects the luminance data for each of the primary colors R, G, and B, analyzes it, and adjusts the color setting to preserve the original colors and make white objects appear white. When selecting Auto-White Balance (AWB) Tracking, you can select five tracking speeds from slow to fastest. The algorithm collects data from the entire image and can work in the following four different modes:

AWB Mode	Description
Off	No color correction performed.
Once	Camera analyzes one image frame, calculates only one set of coefficients, and corrects all subsequent frames with this set of coefficients.
AWB Tracking	Camera analyzes every frame, derives a set of correction coefficients for each frame, and applies them to the next frame.
Manual	Camera uses the correction coefficients you enter.

Table 19: Automatic white balance modes.

4.16 Transfer Function Correction – User LUT

The user defined LUT (Lookup Table) feature allows you to modify and transform the original video data into any arbitrary value (Figure 58). You can transform any 12-bit value into any other 12-bit value. The camera supports two separate lookup tables, each consisting of 4096 entries, with each entry being 12 bits wide. The first LUT is factory programmed with a standard Gamma 0.45. The factory does not pre-program the second LUT. You can modify both LUTs (Appendix A - Creating Tables) and upload your custom LUT using the Cheetah configuration software.

Figure 58: Lookup Table.

4.16.1 Standard Gamma Correction

The image generated by the camera normally appears for viewing on a monitor. However, the monitor image does not have a linear transfer function, that is, the display brightness is not linearly proportional to the scene brightness captured by the camera. As the object brightness dims, the brightness of the display correspondingly lowers. At a certain brightness level, the scene brightness decrease does not lead to a corresponding display brightness decrease. The same is valid if the brightness is increased. This is because the display has a nonlinear transfer function and a brightness dynamic range much lower than the camera. The camera has a built-in transfer function to compensate for this non-linearity called gamma correction. If enabled, the video signal transforms by the following non-linear function close to the square root function (0.45 power). In the digital domain, this is a nonlinear conversion from 12-bit to 12-bit (Figure 59).

$$\text{Output signal [V]} = (\text{input signal [V]})^{0.45} \qquad\qquad (2.4)$$
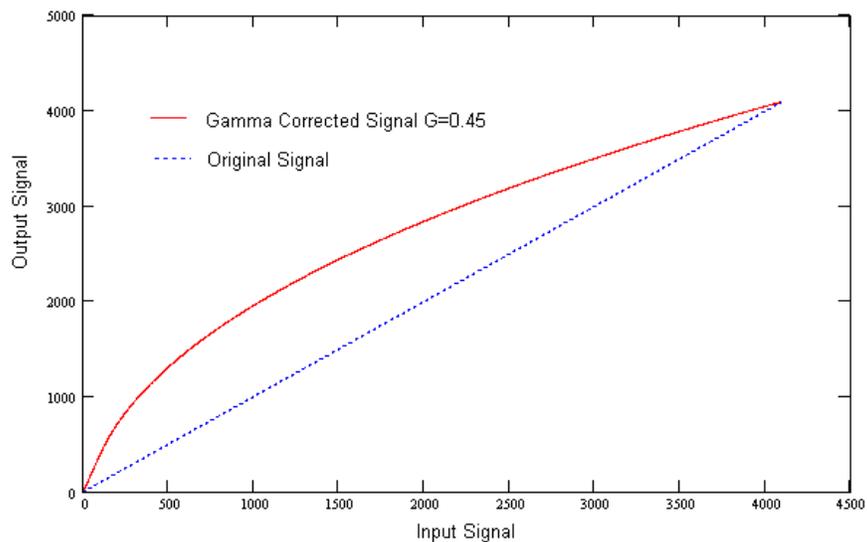
Figure 59: Gamma Corrected Video Signal.

4.16.2 User Defined LUT

You can define any 12-bit to 12-bit transformation as a user LUT and upload it to the camera using the configuration utility software. You can specify a transfer function to match the camera's dynamic range to the scene's dynamic range. There are no limitations to the profile of the function. The LUT must include all possible input values (0 to 4095) (Figure 60).
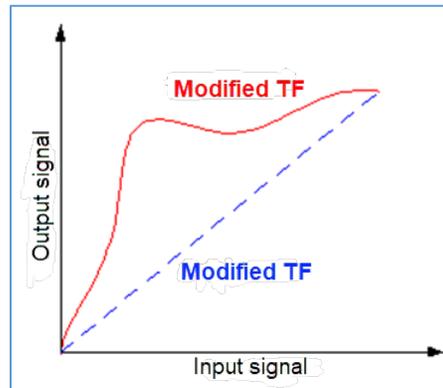

Figure 60: Custom LUT.

4.17 Defective Pixel Correction

A CMOS imager is composed of a two-dimensional array of light sensitive pixels. In general, the majority of the pixels have similar sensitivity, but some deviate from the average pixel sensitivity. A defective pixel is one whose response deviates by more than 15% from the average response. In extreme cases, these pixels fixate as black or white and are non-responsive to light. There are two major types of pixel defects: Defective and Hot.

1. **Defective**. These are pixels whose sensitivity deviates more than 15% due to fluctuations in the CMOS manufacturing process. During final camera testing at the factory, inspection identifies and automatically corrects up to 1024 defective pixels using defective pixel correction. Two types of defective pixels are possible:
    a. **Dark pixels.** These are pixels with sensitivity lower than the sensitivity of the adjacent pixels. In some cases, these pixels will have no response (completely dark).
    b. **Bright pixels.** These are pixels with sensitivity higher than the sensitivity of the adjacent pixels. In some cases, these pixels will have full response (completely bright).
2. **Hot.** These are pixels that in normal camera operation behave as normal pixels (sensitivity equal to one of the adjacent pixels), but during long time integration behave as a high intensity bright pixel. In some cases, pixels will have full response (completely bright). During final camera testing at the factory, inspection identifies and automatically corrects up to 8192 hot pixels using hot pixel correction.

4.17.1 Static Pixel Correction

Static defective and hot pixel correction works with predetermined and preloaded defective and hot pixel maps. During factory final testing, manufacturing engineers run a program specially designed to identify these defective and hot pixels. The program creates a map file listing the coordinates (row and column) of every defective pixel. Engineering downloads the file, called a Defect Pixel Map (DPM), into the camera's non-volatile memory. You can create and upload your own DPM file to the camera to meet your own requirements. When using Defective Pixel Correction, the camera compares each pixel's coordinates with entries in the defect map. If it finds a match, the camera corrects the defective pixel.

4.17.2 Dynamic Pixel Correction

Dynamic pixel correction works without preloaded pixel maps. Instead, the camera determines which pixels need correction and performs the correction automatically. Static and Dynamic Defective Pixel Correction and Hot Pixel Correction can be enabled independently or simultaneously. The dynamic threshold can be set to a value between 0 and 4096 (12-bit). The threshold determines how much a pixel can deviate from neighboring pixels (either brighter or darker) before the camera considers the pixel defective and applies correction to it.

4.18 Camera Interface

4.18.1 Status LED

The camera has a dual red-green LED located on the back panel. The LED color and light pattern indicate the camera status and mode of operation (2.2.1 LED).

4.18.2 Temperature Monitor

The camera's built-in temperature sensor monitors the internal camera temperature. The sensor monitors on the hottest spot in the camera. The internal camera temperature is displayed on the Camera Configuration Utility screen and can be queried by the user at any time (refer to Camera Configuration section).

4.18.3 Exposure Time Monitor

The camera has a built-in exposure time monitor. In any mode of operation (normal, AOI, and so on), you can query the camera for the current exposure time by issuing a command (refer to the Exposure Control section). The camera returns the current camera integration time in units of microseconds.

4.18.4 Frame Time Monitor

In any mode of operation (normal, AOI, and so on), you can query the camera for the current frame rate by issuing a command (refer to the Exposure Control section). The

camera's built-in frame rate monitor returns the current camera speed in units of frames per second.

4.18.5 Current image size

The camera image size can change based on a camera feature selected. In any mode of operation (i.e. normal, AOI, and so on), you can query the camera for the current image size by issuing a command (refer to the Image Size section). The camera returns the current camera image size (in pixels x lines).

Appendix A - Creating Tables

This appendix provides a reference on how to create lookup tables, defective pixel maps, and hot pixel maps.

A.1 Creating LUT Tables

You can create a look-up table (LUT) file using any standard ASCII text editor such as Microsoft Notepad or similar. You can also use a spreadsheet program like Microsoft Excel by converting the spreadsheet to a comma delimited (**.csv**) file. When finished creating the file, you must rename it to include the **.lut** extension.

You can also use any spreadsheet or mathematical program capable of generating a **.csv** file.

TIP (i)

Regardless of the software application you use to create a LUT, you <u>must</u> rename the file to include the **.lut** file extension. The **.lut** file has two main sections: a header and a table.

A.1.1 Using an ASCII Text Editor

The header section of a file created with an ASCII editor like Microsoft Notepad is a free text area of up to 256 ASCII characters. You must end each line of the header section with a comma. The table section of the file contains an array of lines for a mono camera and three times the number of lines for a color camera. Each line will contain an input value followed by a comma and an output value. The input values represent incoming pixels; output values represent the conversion value of each pixel at output.

The following example shows the format of the **.lut** file for a mono camera with 4096 lines:

```
-- Look Up Table input file example,
-- lines beginning with two dashes are comments,
-- and are ignored by parser,
:Header,
-- this is the text that will get displayed with a 'glh'
command,
Function is 'Negative Image',
Created by John Doe,
Date 1/14/09,
:Table,
-- input output,
     0,4095
     1,4094
     2,4093
     3,4092
     4,4091
```

```
         :
     4095,0
```

A.1.2 Using Microsoft Excel

You can create the **.lut** file in Excel as follows:

- Create the spreadsheet as shown below (note that 1024 (1024*3) rows are required in the table).
- Add the necessary equations into the output cells to generate the transfer function required.
- Save the file as a **.csv** file (comma-delimited format).
- Rename the **.csv** file to the **.lut** file extension.
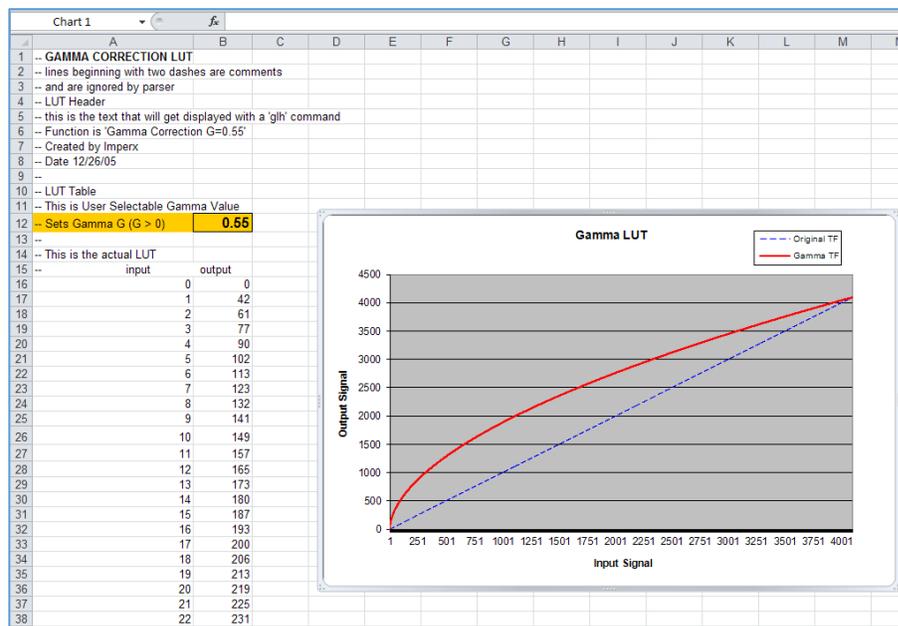
Figure 61: Sample spreadsheet.

# A.2 Creating Corrective Maps

The camera includes a Defective Pixel Map (DPM) and Hot Pixel Map (HPM). You can create your own DPM or HPM file using any standard ASCII text editor or Microsoft Excel. Additionally, you can use any spreadsheet or mathematical program capable of generating a comma delimited (**.csv**) file.

When creating your own corrective map, you must apply a **.dpm** extension for a DPM map and an **.hpm** extension for a HPM map. The **.dpm** or **.hpm** file has two main sections: header and table. The header section is a free text area up to 256 ASCII characters. You must terminate each line of the header section with a comma. The table section of the file contains an array of lines with each line containing an X (pixel number) value followed by a comma and a Y (line number) value. List all pixels in the DPM or HPM in order of

increasing Y location. If the Y location is identical, the listing is in order of increasing X location. After editing, save each file with the appropriate file extension. The maximum number of pixels in the DPM list is 128. The maximum number in the HPM list is 1024.

The following example shows how to create a simple DPM.

1. Locate the defective pixels in the camera.
2. Place the defective pixel coordinates in the DPM file in ascending (increasing) numerical order of the Row (Y) coordinate. The value of all Y coordinates should progressively increase as you look down the list of X,Y coordinates.
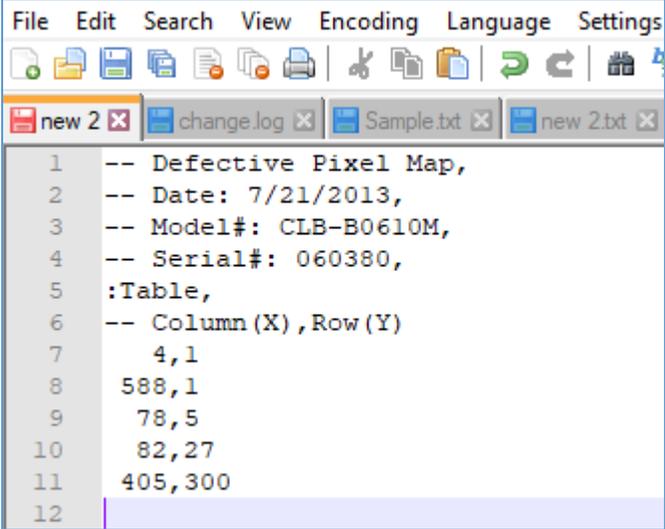

```
File  Edit  Search  View  Encoding  Language  Settings

new 2    change.log    Sample.txt    new 2.txt
  1    -- Defective Pixel Map,
  2    -- Date: 7/21/2013,
  3    -- Model#: CLB-B0610M,
  4    -- Serial#: 060380,
  5    :Table,
  6    -- Column(X),Row(Y)
  7       4,1
  8     588,1
  9      78,5
 10      82,27
 11     405,300
 12
```

Figure 62: Map file example. List pixel coordinates in increasing order based on Row (Y) coordinates.