IMPERX

Cheetah Python CMOS Cameras

User Manual

with Camera Link® Interface

The Imperx Cheetah C5180, C4181, and C4180 CMOS cameras provide exceptional video image quality in a ruggedized design. The cameras use 25-, 16-, and 12-megapixel ON Semiconductor Python image sensors to produce exceptional quality image with low noise and efficient, optimized internal thermal distribution.

Revision 2.5

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.

Imperx, Inc. | 6421 Congress Ave. | Boca Raton, FL, 33487
US Phone: +1 (561) 989-0006

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
Rev 1.0	10/30/15	K. Wetzel	Initial Pre-Release l
Rev 1.1	4/07/16	K. Wetzel	Added Register and GUI info. Input from Gennady
Rev 1.2	4/20/16	K. Wetzel	Updated CamConfig registers and C3880 frame rates
Rev 1.3	5/04/16	K. Wetzel	Updated minimum ROI width to 320
Rev 1.4	5/25/16	K. Wetzel	Update Figure 51 description, removed single tap mode from Figures 15, 16 and 17. Zero ROT not supported in Averaging mode.
Rev 1.5	6/07/16	K. Wetzel	Updated PG period and width in Section 2.9
Rev 1.6	7/22/16	K. Wetzel	Updated Mechanical Drawings in 1.6.4, Cheetah images and Appendix E Power Supply Schematic
Rev 1.7	8/19/2016	M.Pangburn	Adjusted Graph/Data and TOC
Rev 1.8	8/19/16	E. Fateyeva	Adjusted Graph/Data, updated logo in header, replaced pyramid image with Cheetah sketch image
Rev 1.9	8/23/2016	M. Pangburn	Review and finalize TOC
Rev 2.0	12/12/2016	R. Johnston	Updated Fixed Frame Period to microseconds, section 3.3.9. Changed 3.17 to 3.17x, section 2.7.1.
Rev 2.1	3/23/2018	R. Johnston	Updated voltage range to 3.3 and 24 volts in Electrical Connectivity section; added AGC/AEC functionality; removed C3880 camera; updated mechanical drawings; reorganized manual formatting; updated minimum exposure time and shutter speed.
2.2	5/7/2018	R. Johnston	Added AEC/AGC Status LED Updated power supply cable lengths and output.
2.3	9/25/2018	K Wetzel	Change min shutter time to ~50 microseconds.
2.4	8/2/19	I. Barabanova	Added Exposure and Gain Correction Speed, sections 3.3.5.9 and 7.4. Added “Usage”, “Min value”, and “Max value” columns, section 7.4. Added ENIR camera model in sections 1.1, 1.4. Added “Firmware build number”, section 7.3. Added lens mounts, section 1.3. Added 1.1.2 CoaXPress, GigE, 10GigE and USB3 interfaces section Removed 1x8, 1x10, 1x12, 2x12, 4x12 modes, section 2.3.3. Updated frame rates in 5.2.3 section. Updated screenshots (AEC/AGC controls, Menu, View Menu, Trigger panel). Added more information on DPM/HPM editing Formatted text and tables.
2.5	1/03/2020	I. Barabanova	Updated Table 2 Added Reference to the Sensor Cleaning Procedure document (in 2.5.3) Removed logos

1 About the 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.

This manual describes the C5180, C4181, and C4180 model cameras operating with the Camera Link® Deca/Full, Camera Link® Medium, and Camera Link® Base output interface.

Table 1: Cheetah C5180, C4181, and C4180 overview

Model	Resolution (H x V)	Resolution (MP)	Type	Frame Rate (max)	Optics	ON Semiconductor Sensor Model
CLF-C5180M	5120 x 5120	25	Mono	32	APS-H	NOIP1SN025KA
CLF-C5180N	5120 x 5120	25	ENIR	32	APS-H	NOIP1FN025KA
CLF-C5180C	5120 x 5120	25	Color	32	APS-H	NOIP1SE025KA
CLF-C4181M	4096 x 4096	16	Mono	50	APS-H	NOIP1SN016KA
CLF-C4181N	4096 x 4096	16	ENIR	50	APS-H	NOIP1FN016KA
CLF-C4181C	4096 x 4096	16	Color	50	APS-H	NOIP1SE016KA
CLF-C4180M	4096 x 3072	12	Mono	67	4/3”	NOIP1SN012KA
CLF-C4180N	4096 x 3072	12	ENIR	67	4/3”	NOIP1FN012KA
CLF-C4180C	4096 x 3072	12	Color	67	4/3”	NOIP1SE012KA

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 Python CMOS image sensors and feature a built-in processing engine, low noise characteristics, and optimized thermal distribution.

The Cheetah C5180, C4181, and C4180 cameras use global shutter operation for exceptionally high frame rates and superior motion capture. The cameras can control exposure time using internal controls or an external pulse width. They support exposure times up to 1 second with 1 µs increments. An Area of Interest (AOI) can be programmed for each acquisition frame, and subsampling or pixel averaging capabilities are also available.

Built-in gamma correction and user-defined look-up table (LUT) capabilities optimize the camera’s dynamic range features. You can also apply defective pixel correction (DPC) and hot pixel correction (HPC) to correct for pixels that are over-responding or under-responding. Auto-White Balance (AWB) is available in color cameras to correct for color temperature.

The cameras have a Camera Link® interface that includes 8/10-bit data transmission with two, four, eight, or ten output taps as well as camera control all on one or two cables.

The cameras are fully programmable via the Camera Link® interface. The adaptability and flexibility of the camera allow it to be used in a wide and diverse range of applications including machine vision, metrology high-definition imaging and surveillance, medical and scientific imaging, intelligent transportation systems, aerial imaging, character recognition, document processing and many more.

1.1.1 Key Features

- Global shutter (GS)
- Monochrome or color
- Enhanced near infrared (NIR) sensitivity version available upon request
- Fast frame rates
- Configurable pixel clock
- Pixel averaging (mono camera only)
- Subsampling
- Area of Interest
- Analog and digital gain controls
- Offset Control
- Three selectable trigger sources: external, pulse generator, or computer
- Built-in pulse generator
- Two programmable output strobes
- White balance: once, manual, or auto
- Two 12-bit look-up tables (LUT)
- Defective pixel and hot pixel correction (DPC/HPC), Fixed pattern noise (FPN) correction
- Two programmable external inputs (one opto-isolated) and two external outputs (one opto-isolated)
- Flat Field Correction (FFC), user-defined and factory
- Camera Link® Base, Medium, Full and Deca support
- Temperature monitor
- Field upgradeable firmware, LUT, DPC, HPC, FFC

1.1.2 CoaXPress, GigE, 10GigE and USB3 interfaces

The C5180, C4181, and C4180 cameras are also available with the following output interfaces:

– CoaXPress®,
– GigE Vision®,
– 10 GigE Vision®,
– USB3.

If you are adding a new C5180, C4181, and C4180 with an interface other than Camera Link® to your system, you can start configuring the camera right away as the key features (refer to 1.1.1 Key Features and 1.2 Technical Specifications sections) remain the same for all camera interfaces. Depending on the output interface, the following parameters may be different:

Table 2: Cheetah Python output interfaces

Feature		Camera Link®	CoaXPress®[1]	GigE Vision®	10 GigE Vision®	USB3
Frame Rate (max)	C5180	32	44 / 80 (C5190)	4.3	40.6	13
	C4181	50	68 / 120 (C4191)	6.2	60.5	20
	C4180	67	90 / 160 (C4190)	8.3	80.4	27
Active Canon EOS Lens mount		Not Supported	Supported	Supported	Supported	Supported
Trigger Sources		External, Pulse generator, Software, Computer	External, Pulse generator, Software, Trigger over CoaXPress (CXP)	External, Pulse generator, Software	External, Pulse generator, Software	External, Pulse generator, Software
Dimensions (W x H x L, mm)		72.0 x 72.0 x 33.8	72.0 x 72.0 x 34.3/ 72.0 x 72.0 x 44.3 (C5190, C4191, C4190)	72.0 x 72.0 x 33.8	72.0 x 72.0 x 72.3	72.0 x 72.0 x 34.7
Operating temperatures		-40 °C to +85 °C	-40 °C to +70 °C	-40 °C to +85 °C	-40 °C to +75 °C	-40 °C to +85 °C
Weight		385 g	379 g	389 g	579.5 g	370 g
Power		12 V (10 V to 33 V) or PoCL	Power over CXP	12 V (5 V to 33 V)	12 V (5 V to 33 V)	12 V (5 V to 33 V)

[1] NOTE: Cheetah Python cameras with the CoaXPress® interface are available in two variations:
1) 2-channel CXP-6 CoaXPress® cameras (CXP-C5180, CXP-C4181, CXP-C4180)
2) 4-channel CXP-6 CoaXPress® cameras (CXP-C5190, CXP-C4191, CXP-C4190)

This User Manual provides information on cameras with the Camera Link® interface only.

For more information and technical documentation on cameras with other interfaces please visit our web site www.imperx.com

1.2 Technical Specifications

The following Tables describe features and specifications that relate to all Cheetah CLF cameras.

Table 3: Cheetah camera general specifications

Features / Specifications	**Cheetah Cameras**
Shutter Operation	Global only
Exposure time	~44 µs minimum
Area of Interest	One
Analog Gain	Up to 10 dB (1x, 1.26x, 1.87x, 3.17x)
Digital Gain	Up to 24 dB
Subsampling	Keep one, skip one
Pixel Averaging (mono)	1x2, 2x1 and 2x2
Auto-White Balance	Yes
Test Image	Static, Dynamic
Defective pixel correction*	Static, Dynamic, User DPM
Hot pixel correction	Static, Dynamic, User HPM
Inputs*	1-LVTTL / 1-Opto-coupled
Outputs*	1-5 V TTL / 1-Opto-coupled
Triggers	Programmable Rising/Falling De-bounce
Pulse Generator	Yes
In-camera Image Processing	2 LUTs
Camera housing	Aluminum
Supply voltage range*	5 V to 33 V DC; 6.5 V to 33 V DC with Canon Lens Control
Upgradeable firmware	Yes
Upgradeable LUT, DPM, FFC	Yes
Environmental – operating	- 40 °C to + 85 °C
Environmental – storage	- 50 °C to + 90 °C
Relative humidity	10% to 90% non-condensing

*The specifications may vary for the different Cheetah Python and Cheetah Pregius camera models.

1.2.1 CLF-C5180 and CLF-C4181 Cameras

Specifications	**C5180**	**C4181**
Active image resolution	5120 x 5120	4096 x 4096
Active image area (H, V)	23.0 mm x 23.0 mm 32.5 mm Diagonal	18.4 mm x 18.4 mm 26.1 mm Diagonal
Pixel size	4.5 µm	4.5 µm
Video output	Digital, 8/10-bit	Digital, 8/10-bit
Output structure	10-Tap	10-Tap
Data clock	85 MHz	85 MHz
Camera interface	DECA/Full/Medium or Base CL	DECA/Full/Medium or Base CL
Camera connector	Dual HDR (26-pin mini CL)	Dual HDR (26-pin mini CL)
Maximum frame rate	26 fps (10-bit), 32 fps (8-bit)	40 fps (10-bit), 50 fps (8-bit)
Dynamic Range	59 dB	59 dB
Shutter Speed	~50 µs to 1 sec	~50 µs to 1 sec
Area of Interest	One	One
Analog gain	0 dB to 10 dB (8 & 10-bit)	0 dB to 10 dB (8 & 10-bit)
Digital gain	0 dB to 24 dB	0 dB to 24 dB
Black level offset	-512 to +511, 1/step	-512 to +511 1/step
User LUT	2 LUTs: gamma, user LUT	2 LUTs: gamma, user LUT
Hardware trigger	Asynchronous; Fast trigger – exposure & readout overlap	Asynchronous; Fast trigger – exposure & readout overlap
Strobe modes	Programmable width, delay	Programmable width, delay
Trigger sources	External, pulse generator, software, computer	External, pulse generator, software, computer
Trigger features	Rising/falling edge, de-glitch, delay, strobe	Rising/falling edge, de-glitch, delay, strobe
Size (W x H x L) - CLB	(72.0 x 72.0 x 33.8) mm	(72.0 x 72.0 x 33.8) mm
Weight	385 g	385 g
Lens mount	F-Mount, M42, passive Canon EOS	F-Mount, M42, passive Canon EOS
Camera Current @ 12V nominal input:	Typical: 0.52 A, Maximum: 0.66 A	Typical: 0.52 A, Maximum: 0.66 A
Environmental – operating	- 40 °C to + 85 °C	- 40 °C to + 85 °C
Environmental – storage	- 50 °C to + 90 °C	- 50 °C to + 90 °C

1.2.2 CLF-C4180 Camera

Specifications	**C4180**
Active image resolution	4096 x 3072
Active image area (H, V)	18.4 mm x 13.8 mm; 23.0 mm Diagonal
Pixel size	4.5 µm
Video output	Digital, 8/10-bit
Output structure	10-Tap
Data clock	85 MHz
Camera interface	DECA/Full/Medium or Base CL
Connector	Dual HDR (26-pin mini CL)
Maximum frame rate	54 fps (10-bit), 67 fps (8-bit)
Dynamic range	59 dB
Shutter Speed	~50 µs to 1 sec
Area of Interest	One
Analog gain	0 dB to 10 dB (8 & 10-bit)
Digital gain	0 dB to 24 dB
Black level offset	-512 to +511, 1/step
User LUT	2 LUTs: gamma, user LUT
Hardware trigger	Asynchronous; Fast trigger – exposure & readout overlap
Strobe modes	Programmable width, delay
Trigger sources	External, pulse generator, software, computer
Trigger features	Rising/falling edge, de-glitch, delay, strobe
Size (W x H x L) - CLB	(72.0 x 72.0 x 33.8) mm
Weight	385 g
Lens mount	F-Mount, M42, passive Canon EOS
Camera Current @ 12V nominal input:	Typical: 0.52 A, Maximum: 0.66 A
Environmental – operating	- 40 °C to + 85 °C
Environmental – storage	- 50 °C to + 90 °C

1.3 Ordering Information

Table 4: Cheetah Camera Ordering Codes

Sample Codes: CLF-C5180M-RE000: Cheetah Monochrome 25 MP camera with Canon EF EOS passive mount and Camera Link Full interface without a filter/customization CLF-C4181C-RF400: Cheetah Color 16 MP camera with F-Mount and Camera Link Full interface featuring clear cover glass filter					
Interface	Camera model	Sensor Type	Ruggedized	Lens Mount	Filter/ customization options
CLF = Camera Link® Full	C5180 – 5120 x 5120 C4180 – 4096 x 3072 C4181 – 4096 x 4096	M = Monochrome N = Enhanced NIR C = Color	R = Ruggedized	F = F-Mount (default) M = M42 E = Canon EF EOS passive C = C-Mount (C4180 only)	000 = none 200 = Color w/out IR filters 400 = Color w/out IR filter replace w/clear cover glass 700 = Mono w/clear cover glass
Note: PS12V04A Power Supply sold separately.					

For any other custom camera configurations, contact Imperx, Inc. at:

Email: sales@imperx.com
Tel.(+1) 561-989-0006
Fax: (+1) 561-989-0045
Visit our website: www.imperx.com

1.4 Technical Support

Each camera is fully tested before shipping. If for some reason the camera is not operational after power up, check the following:

1. Check the power supply and all I/O cables. Make sure that all the connectors are firmly attached.
2. Check the status LED and verify that it is steady ON, if not – refer to the section 2.4 Camera LED Status Indicators.
3. Enable the test mode (refer to the 4.8.6 Data Output Control) and verify that the communication between the frame grabber and the camera is established. If the test pattern is not present, power off the camera, check all the cabling, frame grabber settings, and computer status.

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 Camera Back Panel

The interface between the Cheetah cameras and outside equipment connects via two connectors and one LED located on the back panel of the camera.
The back panel includes (see Figure 1):

1. Two camera outputs – standard Full Camera Link Mini connectors provides data, sync, control, and serial interface.
2. Male 12-pin Power Connector – provides power and I/O interface.
3. USB type B programming/SPI connector.
4. Status LED – indicates the status of the camera.
5. Model / Serial Number – shows camera model and serial number.

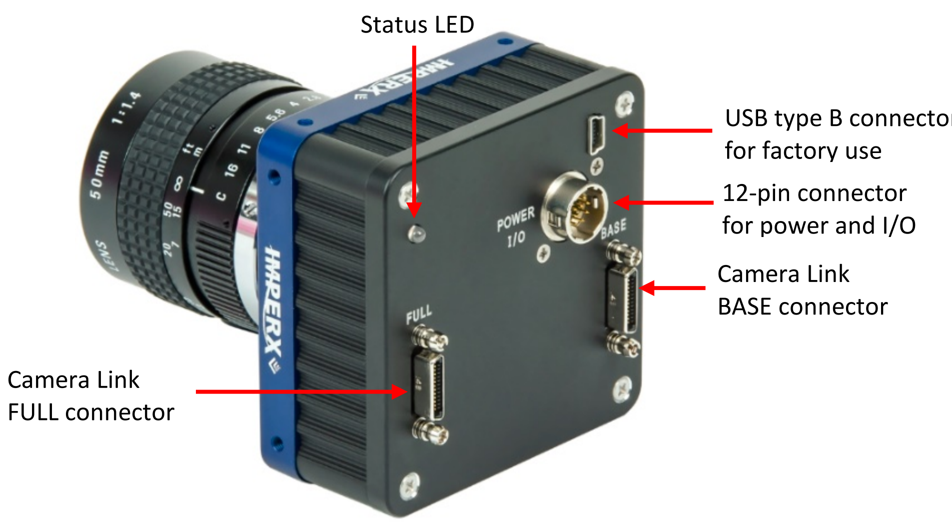


Figure 1: CLF Camera back panel, Deca, Full, Medium, or Base

2.1.1 Power Supply

The camera requires a 12-volt power supply. Imperx recommends purchasing the optional Imperx PS12V04 power supply. The PS12V04A power supply also provides connectors for trigger input (black) and strobe output (white).

Figure 2: PS12V04A standard power supply (ordered separately)

2.1.1.1 Power Supply Specs

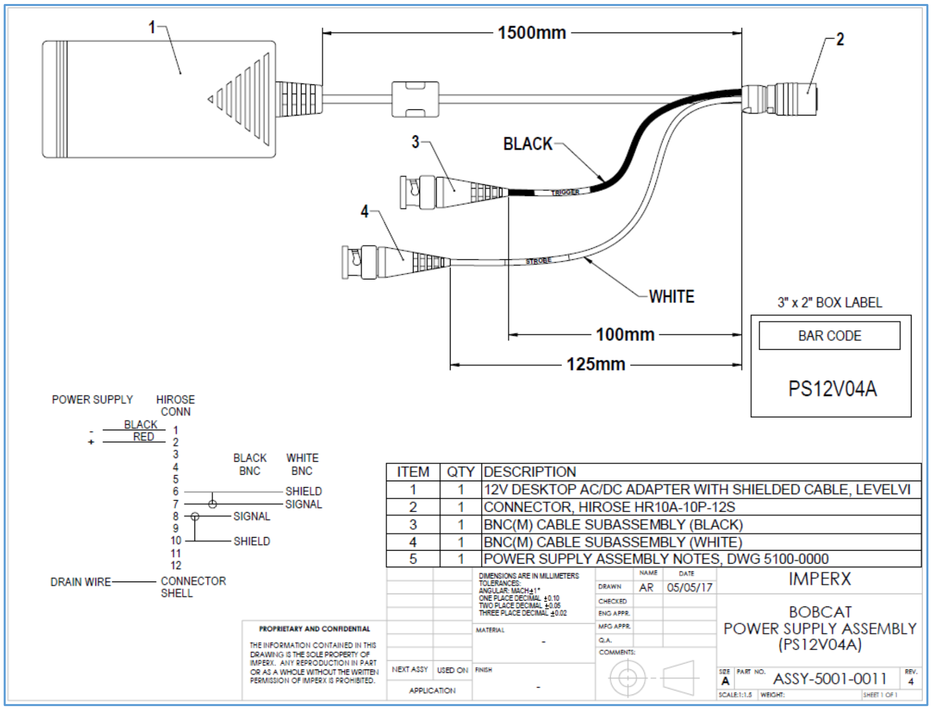
Cable length:
Supplied AC power input cable (IEC): 1.8m (6') 100 - 240 V AC, 50 - 60 Hz 1A
Power supply Output (+12 V): 1.5m (5') ± 15cm (6") connector HIROSE #HR10A-10P-12S
Strobe & Trigger: 15cm (6") ± 1cm (0.5") connector BNC male.

Electrical:

Over-Voltage Protective Installation
Short-circuit Protective Installation
Protection Type: Auto-Recovery
12 V to 13 V DC, 12.6 V DC nominal, 2 A.
Load regulation ± 5%
Ripple & Noise 1% Max.

Regulatory:

Class 1
Safety standards UL60950-1, EN60950-1, IEC60950-1
Safety (1) EMC UL/CUL, CE, TUV, DoIR+C-Tick, Semko, CCC, FCC
Safety (2) BSMI, FCC



ITEM	QTY	DESCRIPTION
1	1	12V DESKTOP AC/DC ADAPTER WITH SHIELDED CABLE, LEVELVI
2	1	CONNECTOR, HIROSE HR10A-10P-12S
3	1	BNC(M) CABLE SUBASSEMBLY (BLACK)
4	1	BNC(M) CABLE SUBASSEMBLY (WHITE)
5	1	POWER SUPPLY ASSEMBLY NOTES, DWG 5100-0000

Figure 3: PS12V04A power supply assembly

2.2 Camera Power Connector

The male 12-pin Hirose connector provides power and all external input/output signals supplied to the camera. Refer to the following tables for connector pin-outs and pin mapping. The connector is a male HIROSE type miniature locking receptacle #HR10A-10R-12PB (71). The optionally purchased power supply is shipped with a power cable that terminates in a female HIROSE plug #HR10A-10P-12S (73).

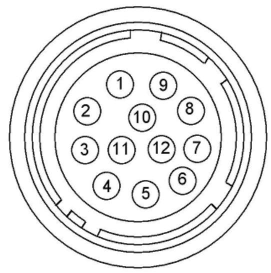


Figure 4: Camera Power Connector (Viewed from rear)

2.2.1 Power Connector Pins

Table 5: Camera Power Connector Pin Mapping

Pin	Signal	Use
1	12 VDC RTN	12 VDC Main Power Return
2	+ 12 VDC	+ 12 VDC Main Power
3	Reserved	Reserved for future RS-232
4	Reserved	Reserved for future RS-232
5	OUT2 RTN	General Purpose Output 2, Contact 1 (Opto-isolated)
6	OUT1 RTN	General Purpose Output 1 Return (TTL)
7	OUT1	General Purpose Output 1 (TTL)
8	IN1	General Purpose Input 1 (Opto-isolated)
9	IN2	General Purpose Input 2 (TTL/LVTTL)
10	IN1 RTN	General Purpose Input 1 Return (Opto-isolated)
11	IN2 RTN	General Purpose Input 2 Return (TTL/LVTTL)
12	OUT2	General Purpose Output 2, Contact 2 (Opto-isolated)

2.2.2 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. Output “OUT 1” is a 5 V TTL (5.0 Volts) compatible signal and output “OUT 2” is opto-isolated. The following four figures show the external input electrical connections and the external output electrical connections.

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.

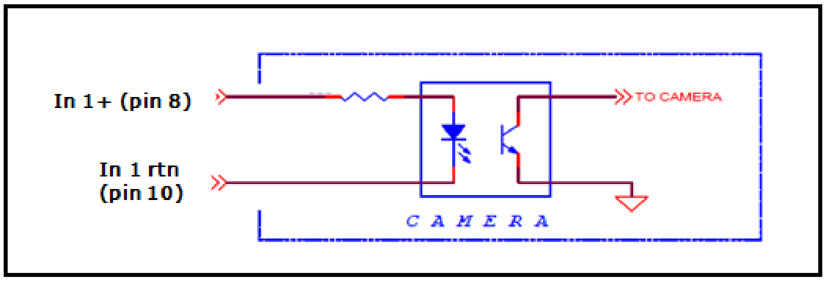


Figure 5: IN1 electrical connection

B. Input IN 2 LVTTL

The input signals "IN 2" and "IN 2 Rtn" are used to interface to a TTL or LVTTL input signal. 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.

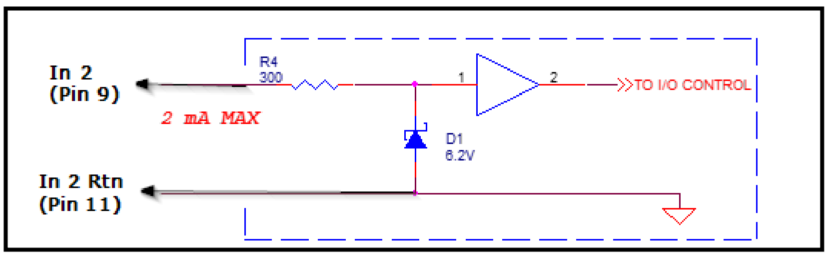


Figure 6: IN 2 electrical connection

C. Output OUT 1 LVTTL

Output OUT 1 is a 5 V TTL (5.0 Volts) compatible signal and the maximum output current MUST NOT exceed 8 mA.

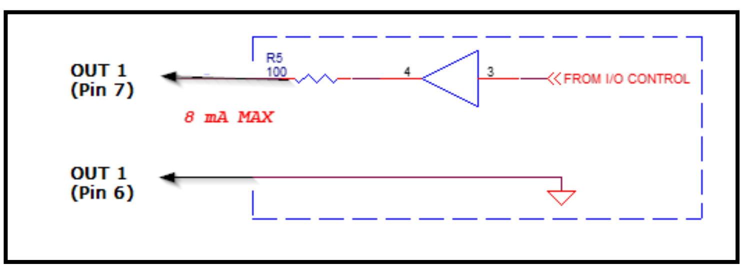


Figure 7: OUT 1 LVTTL electrical connection

D. Output OUT 2 - Opto-isolated

Output OUT 2 is an optically isolated switch. There is no pull-up voltage on either contact. The voltage across OUT 2 Contact 1 and OUT 2 Contact 2 **MUST NOT** exceed 25 volts and the current through the switch **MUST NOT** exceed 50 mA.

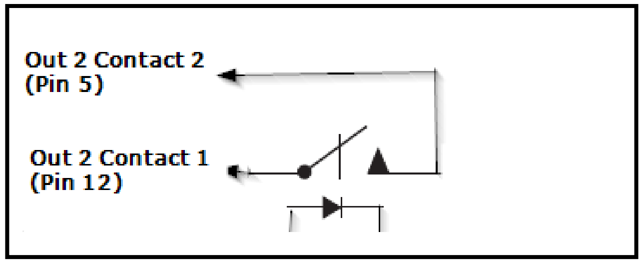


Figure 8: OUT 2 Opto-Isolated electrical connection

2.3 Camera Link Signal Mapping

Camera data output complies with Deca (80-bit), Full (64-bit), Medium (48-bit) and Base (24-bit) Camera Link standards, up to 80 data bits, 4 sync signals (LVAL, FVAL, DVAL and User Out), 1 reference clock, 2 external inputs CC1, CC2, and a bi-directional serial interface. The Camera Link output connectors are shown in Figure 9 and Figure 10 with the corresponding bit and port mapping described below each figure

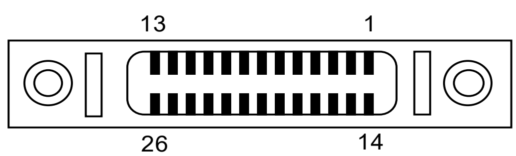


Figure 9: CLF Camera output connector 1 (BASE)

Table 6: CLF Camera Output Connector 1 (BASE) – Signal Mapping

Cable Name	Pin	CL Signal	Type	Description
Base Wire	1	12 VDC Power	Power	Power Base
Base Wire	14	Power Return	Ground	Ground
- PAIR 1	2	- X 0	LVDS - Out	Camera Link Channel Tx
+ PAIR 1	15	+ X 0	LVDS - Out	Camera Link Channel Tx
- PAIR 2	3	- X 1	LVDS - Out	Camera Link Channel Tx
+ PAIR 2	16	+ X 1	LVDS - Out	Camera Link Channel Tx
- PAIR 3	4	- X 2	LVDS - Out	Camera Link Channel Tx
+ PAIR 3	17	+ X 2	LVDS - Out	Camera Link Channel Tx
- PAIR 4	5	- X CLK	LVDS - Out	Camera Link Clock Tx
+ PAIR 4	18	+ X CLK	LVDS - Out	Camera Link Clock Tx
- PAIR 5	6	- X 3	LVDS - Out	Camera Link Channel Tx
+ PAIR 5	19	+ X 3	LVDS - Out	Camera Link Channel Tx
+ PAIR 6	7	+ SerTC	LVDS - In	Serial Data Receiver
- PAIR 6	20	- SerTC	LVDS - In	Serial Data Receiver
- PAIR 7	8	- SerTFG	LVDS - Out	Serial Data Transmitter
+ PAIR 7	21	+ SerTFG	LVDS - Out	Serial Data Transmitter
- PAIR 8	9	- CC 1	LVDS - In	User Selectable Input
+ PAIR 8	22	+ CC 1	LVDS - In	User Selectable Input

Table 6: CLF Camera Output Connector 1 (BASE) – Signal Mapping (continued)

Cable Name	Pin	CL Signal	Type	Description
+ PAIR 9	10	+ CC2	LVDS - In	User Selectable Input
- PAIR 9	23	- CC2	LVDS - In	User Selectable Input
- PAIR 10	11	N/C	N/C	N/C
+ PAIR 10	24	N/C	N/C	N/C
+ PAIR 11	12	N/C	N/C	N/C
- PAIR 11	25	N/C	N/C	N/C
Base Wire	13	Power Return	Ground	Ground
Base Wire	26	12 VDC Power	Power	Power Base

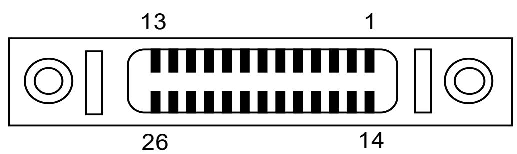


Figure 10: CLF Camera output connector 2 (FULL)

Table 7: CLF Camera Output Connector 2 (FULL) – Signal Mapping

Cable Name	Pin	CL Signal	Type	Description
Base Wire	1	12 VDC Power	Power	Power Base
Base Wire	14	Power Return	Ground	Ground
- PAIR 1	2	- Y 0	LVDS - Out	Camera Link Channel Tx
+ PAIR 1	15	+ Y 0	LVDS - Out	Camera Link Channel Tx
- PAIR 2	3	- Y 1	LVDS - Out	Camera Link Channel Tx
+ PAIR 2	16	+ Y 1	LVDS - Out	Camera Link Channel Tx
- PAIR 3	4	- Y 2	LVDS - Out	Camera Link Channel Tx
+ PAIR 3	17	+ Y 2	LVDS - Out	Camera Link Channel Tx
- PAIR 4	5	- Y CLK	LVDS - Out	Camera Link Clock Tx
+ PAIR 4	18	+ Y CLK	LVDS - Out	Camera Link Clock Tx
- PAIR 5	6	- Y 3	LVDS - Out	Camera Link Channel Tx
+ PAIR 5	19	+ Y 3	LVDS - Out	Camera Link Channel Tx
+ PAIR 6	7	unused	LVDS - In	Serial Data Receiver
- PAIR 6	20	unused	LVDS - In	Serial Data Receiver
- PAIR 7	8	- Z 0	LVDS - Out	Camera Link Channel Tx
+ PAIR 7	21	+ Z 0	LVDS - Out	Camera Link Channel Tx
- PAIR 8	9	- Z 1	LVDS - Out	Camera Link Channel Tx
+ PAIR 8	22	+ Z 1	LVDS - Out	Camera Link Channel Tx
+ PAIR 9	10	- Z 2	LVDS - Out	Camera Link Channel Tx
- PAIR 9	23	+ Z 2	LVDS - Out	Camera Link Channel Tx
- PAIR 10	11	-Z CLK	LVDS - Out	Camera Link Clock Tx

Table 7: CLF Camera Output Connector 2 (FULL) – Signal Mapping (continued)

Cable Name	Pin	CL Signal	Type	Description
+ PAIR 10	24	+ Z CLK	LVDS - Out	Camera Link Clock Tx
+ PAIR 11	12	Z 3	LVDS - Out	Camera Link Channel Tx
- PAIR 11	25	+Z 3	LVDS - Out	Camera Link Channel Tx
Base Wire	13	Power Return	Ground	Ground
Base Wire	26	12 VDC Power	Power	Power Base

2.3.1 Camera Link Physical Layer to Camera Link Receiver Bits

The timing diagram below describes how the Camera Link bits are transmitted over the physical link. In the diagram, X0, X1, X2, and X3 are the physical connections. Seven data packets of four bits each are sent during each clock cycle and provide the 28 Camera Link Bits. Camera Link bits 0, 8, 19, and 27 are received over X0 to X3 in the first transfer, and bits 1, 9, 20, and 5 are received in the second transfer cycle. The timing for Y0 to Y3 and Z0 to Z3 physical connections is the same as X0 to X3.

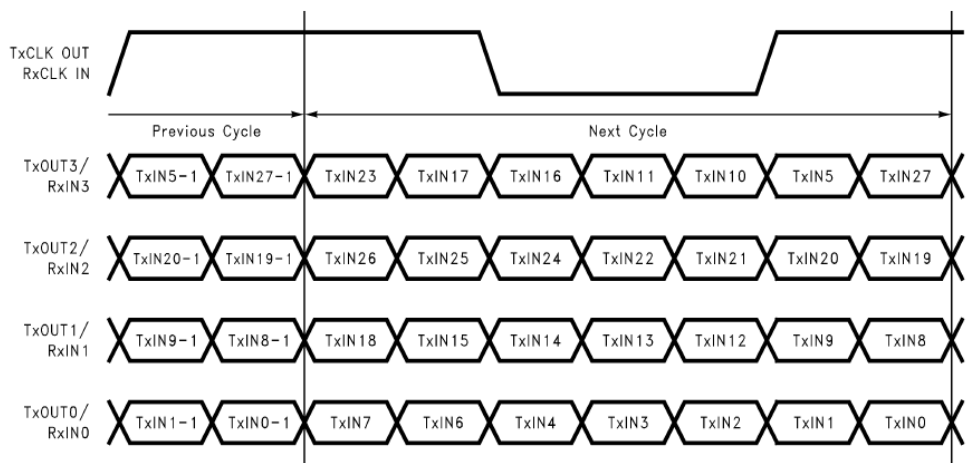


Figure 11: Camera Link bit sequence over the physical connection

2.3.2 Camera Link Bit to Port Bit assignments

The following connector tables describe how the Camera Link Receiver bits received from X0-X3, Y0-Y3 and Z0-Z3 physical connections on CL connectors #1 (BASE) and are translated into the Camera Link Port bits based on the selected Camera Link Configuration: Base, Medium, Full or Deca.

Table 8: Camera Link Connector #1 (BASE) (X0-X3)

Camera Link X0-X3			
		10tap8bit	8tap10bit
CL_RCVR_Bits	Base	Deca	Deca
0	A0	A0	A0
1	A1	A1	A1

Table 8: Camera Link Connector #1 (BASE) (X0-X3) (continued)

Camera Link X0-X3			
		10tap8bit	8tap10bit
CL_RCVR_Bits	Base	Deca	Deca
2	A2	A2	A2
3	A3	A3	A3
4	A4	A4	A4
5	A7	A5	A7
6	A5	A6	A5
7	B0	A7	B0
8	B1	B0	B1
9	B2	B1	B2
10	B6	B2	B6
11	B7	B3	B7
12	B3	B4	B3
13	B4	B5	B4
14	B5	B6	B5
15	C0	B7	C0
16	C6	C0	C6
17	C7	C1	C7
18	C1	C2	C1
19	C2	C3	C2
20	C3	C4	C3
21	C4	C5	C4
22	C5	C6	C5
23	SPR	C7	I1
24	LVAL	LVAL	LVAL
25	FVAL	FVAL	FVAL
26	DVAL	D0	I0
27	A6	D1	A6

Table 9: Camera Link Connector #2 (FULL) (Y0-Y3)

Camera Link Y0-Y3			
		10tap8bit	8tap10bit
CL_RCVR_Bits	Med	Deca	Deca
0	D0	D2	D0
1	D1	D3	D1
2	D2	D4	D2
3	D3	D5	D3

Table 9: Camera Link Connector #2 (FULL) (Y0-Y3) (continued)

Camera Link Y0-Y3			
		10tap8bit	8tap10bit
CL_RCVR_Bits	Med	Deca	Deca
4	D4	D6	D4
5	D7	D7	D7
6	D5	E0	D5
7	E0	E1	E0
8	E1	E2	E1
9	E2	E3	E2
10	E6	E4	E6
11	E7	E5	E7
12	E3	E6	E3
13	E4	E7	E4
14	E5	F0	E5
15	F0	F1	F0
16	F6	F2	F6
17	F7	F3	F7
18	F1	F4	F1
19	F2	F5	F2
20	F3	F6	F3
21	F4	F7	F4
22	F5	G0	F5
23	SPR	G1	I4
24	LVAL	G2	LVAL
25	FVAL	G3	I2
26	DVAL	G4	I3
27	D6	LVAL	D6

Table 10: Camera Link Connector #2 (Z0-Z3)

Camera Link Z0-Z3			
		10tap8bit	8tap10bit
CL_RCVR_Bits	Full	Deca	Deca
0	G0	G5	G0
1	G1	G6	G1
2	G2	G7	G2
3	G3	H0	G3
4	G4	H1	G4
5	G7	H2	G7

Table 10: Camera Link Connector #2 (Z0-Z3) (continued)

Camera Link Z0-Z3			
		10tap8bit	8tap10bit
CL_RCVR_Bits	Full	Deca	Deca
6	G5	H3	G5
7	H0	H4	H0
8	H1	H5	H1
9	H2	H6	H2
10	H6	H7	H6
11	H7	I0	H7
12	H3	I1	H3
13	H4	I2	H4
14	H5	I3	H5
15	-	I4	I5
16	-	I5	J3
17	-	I6	J4
18	-	I7	I6
19	-	J0	I7
20	-	J1	J0
21	-	J2	J1
22	-	J3	J2
23	SPR	J4	J7
24	LVAL	J5	LVAL
25	FVAL	J6	J5
26	DVAL	J7	J6
27	G6	LVAL	G6

2.3.3 Camera Link Port assignments based on selected output configuration

Table 11: Supported Output Configurations

2x8	2x10	4x8	4x10	8x8	10x8	8x10	MODE
✓	✓						Base
		✓	✓				Medium
				✓			Full
					✓	✓	Deca

Table 12: Image data bit-to-port assignments– Base modes

Port C								Port B								Port A								
c7	c6	c5	C4	c3	c2	c1	c0	b7	b6	b5	b4	b3	b2	b1	b0	a7	a6	a5	a4	a3	a2	a1	a0	MODE
								B7	B6	B5	B4	B3	B2	B1	B0	A7	A6	A5	A4	A3	A2	A1	A0	2x8
B7	B6	B5	B4	B3	B2	B1	B0			B9	B8			A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	2x10

Table 13: Image data bit-to-port assignments– Medium modes

Port C								Port B								Port A								
Port F								Port E								Port D								
c7	c6	c5	c4	c3	c2	c1	c0	b7	b6	b5	b4	b3	b2	b1	b0	a7	a6	a5	a4	a3	a2	a1	a0	
f7	f6	f5	f4	f3	f2	f1	f0	e7	e6	e5	e4	e3	e2	e1	e0	d7	d6	d5	d4	d3	d2	d1	d0	MODE
C7	C6	C5	C4	C3	C2	C1	C0	B7	B6	B5	B4	B3	B2	B1	B0	A7	A6	A5	A4	A3	A2	A1	A0	4x8
																D7	D6	D5	D4	D3	D2	D1	D0	
B7	B6	B5	B4	B3	B2	B1	B0			B9	B8			A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	4x10
		D9	D8			C9	C8	C7	C6	C5	C4	C3	C2	C1	C0	D7	D6	D5	D4	D3	D2	D1	D0	

Table 14: Image data bit-to-port assignments– Full mode

Port C								Port B								Port A								
Port F								Port E								Port D								
---								Port H								Port G								
c7	c6	c5	c4	c3	c2	c1	c0	b7	b6	b5	b4	b3	b2	b1	b0	a7	a6	a5	a4	a3	a2	a1	a0	
f7	f6	f5	f4	f3	f2	f1	f0	e7	e6	e5	e4	e3	e2	e1	e0	d7	d6	d5	d4	d3	d2	d1	d0	
								h7	h6	h5	h4	h3	h2	h1	h0	g7	g6	g5	g4	g3	g2	g1	g0	MODE
C7	C6	C5	C4	C3	C2	C1	C0	B7	B6	B5	B4	B3	B2	B1	B0	A7	A6	A5	A4	A3	A2	A1	A0	8x8
F7	F6	F5	F4	F3	F2	F1	F0	E7	E6	E5	E4	E3	E2	E1	E0	D7	D6	D5	D4	D3	D2	D1	D0	
								H7	H6	H5	H4	H3	H2	H1	H0	G7	G6	G5	G4	G3	G2	G1	G0	

Table 15: Image data bit-to-port assignments– Deca modes

Port C								Port B								Port A								
Port F								Port E								Port D								
Port I								Port H								Port G								
---								---								Port J								
c7	c6	c5	c4	c3	c2	c1	c0	b7	b6	b5	b4	b3	b2	b1	b0	a7	a6	a5	a4	a3	a2	a1	a0	
f7	f6	f5	f4	f3	f2	f1	f0	e7	e6	e5	e4	e3	e2	e1	e0	d7	d6	d5	d4	d3	d2	d1	d0	
i7	i6	i5	i4	i3	i2	i1	i0	h7	h6	h5	h4	h3	h2	h1	h0	g7	g6	g5	g4	g3	g2	g1	g0	
																j7	j6	j5	j4	j3	j2	j1	j0	MODE
C7	C6	C5	C4	C3	C2	C1	C0	B7	B6	B5	B4	B3	B2	B1	B0	A7	A6	A5	A4	A3	A2	A1	A0	10x8
F7	F6	F5	F4	F3	F2	F1	F0	E7	E6	E5	E4	E3	E2	E1	E0	D7	D6	D5	D4	D3	D2	D1	D0	
I7	I6	I5	I4	I3	I2	I1	I0	H7	H6	H5	H4	H3	H2	H1	H0	G7	G6	G5	G4	G3	G2	G1	G0	
																J7	J6	J5	J4	J3	J2	J1	J0	
C9	C8	C7	C6	C5	C4	C3	C2	B9	B8	B7	B6	B5	B4	B3	B2	A9	A8	A7	A6	A5	A4	A3	A2	8x10
F9	F8	F7	F6	F5	F4	F3	F2	E9	E8	E7	E6	E5	E4	E3	E2	D9	D8	D7	D6	D5	D4	D3	D2	
D1	D0	C1	C0	B1	B0	A1	A0	H9	H8	H7	H6	H5	H4	H3	H2	G9	G8	G7	G6	G5	G4	G3	G2	
																H1	H0	G1	G0	F1	F0	E1	E0	

2.4 Camera LED Status Indicators

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:

LED Condition	Status Indication
Green steady ON	Normal operation. You should see a normal image coming out of the camera.
Green blinks at ~ 0.5 Hz	Indicates triggering mode.
Amber steady ON	Test mode enabled.
Amber blinking.	Camera in AEC/AGC mode.
LED OFF	Power not present. Possible power supply failure or faulty external AC/ adapter. Re-power camera and load factory settings. If LED still OFF, contact factory.

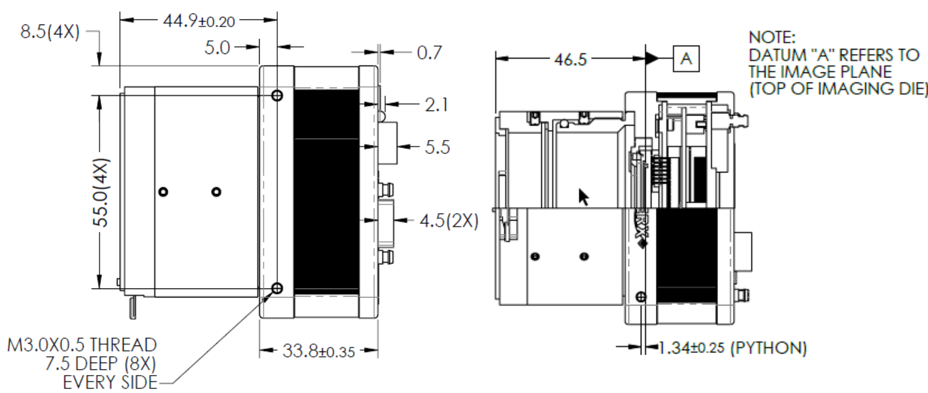
2.5 Mechanical, Optical, Environmental

2.5.1 Mechanicals

The camera housing is manufactured of high quality aluminum. For maximum flexibility, the camera has eight (8) M3X0.5mm mounting screws, located towards the front and the back. An additional plate with ¼-20 UNC (tripod mount) and hardware is shipped with each camera. All dimensions are in millimeters.

2.5.1.1 Drawings of C5180, C4181, and C4180

Side views:



Front and Back views:

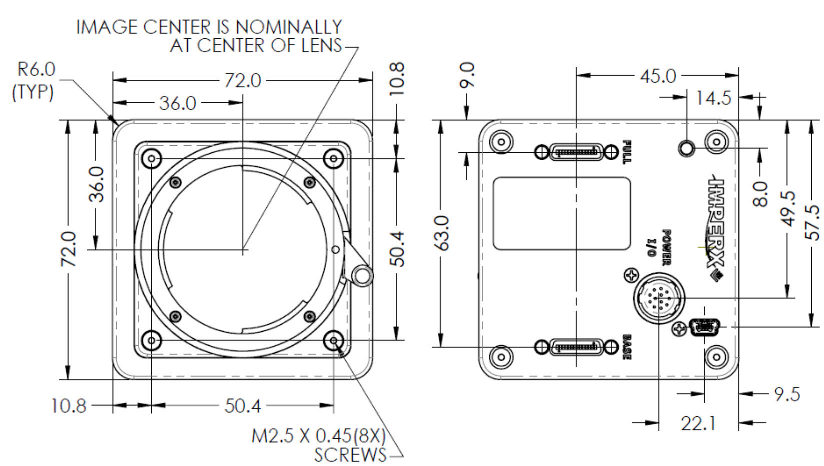


Figure 12: Camera Link C5180, C4181, and C4180 Mechanical Drawings

2.5.2 Optical

The camera's 72 mm x 72 mm cross-section comes with an adapter for F-mount lenses, which have a 46.50 mm back focal distance.

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

The cameras are highly sensitive in the (IR) spectral region. Color cameras have an IR cut-off filter installed. The monochrome cameras come without IR cut filter. If necessary, an IR filter (1 mm thickness or less) can be inserted under the front lens bezel.

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.

2.5.3 Environmental

The camera is designed to operate from **-**40 °C to 85 °C in a dry environment. The relative humidity should not exceed 90% non-condensing. Always keep the camera as cool as possible. Always allow sufficient time for temperature equalization, if the camera has been kept 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 or in close proximity to an intensive heat source, strong magnetic fields, or strong electric fields.
3. Avoid touching or cleaning the front surface of the optical sensor. If the sensor needs to be cleaned, use a soft lint free cloth and an optical cleaning fluid.
   <u>Do not</u> use methylated alcohol!
   Please refer to the Sensor Cleaning Procedure document found on the camera's information USB stick or contact Imperx support for cleaning procedures.

3 Camera Configuration

3.1 Overview

The Cheetah series of cameras are highly programmable and flexible. You can control all of the cameras resources (internal registers, video amplifiers and parameter FLASH). You communicate with the camera using a simple, register-based, command protocol via the Camera Link's serial interface. The interface is bi-directional in which you issue commands to the camera, and the camera issues responses (either status or info). You can configure and monitor all camera registers and resources. Use the Cheetah camera configurator (CamConfig) graphical user interface (GUI) to program the camera's parameters.

3.2 Configuration

3.2.1 Configuration Memory – parameter FLASH

The camera has built-in configuration memory divided into 4 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 and retrieve these registers via commands. The workspace is RAM-based and upon power down, all camera registers are cleared. The factory-space segment is ROM based, write protected, and contains the default camera settings. This space is available for read operations only. The user-space #1 and user-space #2 are non-volatile, FLASH based, and used to store two user-defined configurations.

Upon power up, the camera firmware loads the work-space registers from the factory-space, user-space #1, or user-space #2 as determined by a boot control register located in the configuration memory. You can program the boot control register (refer to 3.3.2.1 Boot From section). At any time, you can instruct the camera to load its workspace with the contents of the factory-space, user-space #1, or user-space #2 (refer to section 3.3.2.2 Load From Factory, 3.3.2.3 Load From User #1, or 3.3.2.4 Load From User #2). Similarly, you can instruct the camera to save the current workspace settings in either user-space #1 or user-space #2 (refer to section 3.3.2.5 Save to User #1 or 3.3.2.6 Save to User #2).

The non-volatile parameter FLASH memory also contains Defective Pixel Map (DPM), Hot Pixel Map (HPM), LUT 1, and LUT 2, which can be loaded to the camera's internal memory upon enabling the corresponding camera feature. You can create your own DPM, HPM, and LUT tables (see chapter 8 Creating Look-up Tables and 9 Creating DPC / HPC Tables) and upload them to the parameter FLASH using the Cheetah Configurator graphical user interface.

3.2.2 Camera Serial Protocol

To access the camera registers and resources, the Camera Link serial interface needs to transmit a sequence of bytes to the camera. This is an RS232, asynchronous, full-duplex, serial protocol, with 1 start bit, 8 data bits, 1 stop bit, no hand shake, and no parity (Figure 13). The default baud rate is configurable (9600, 19200, 38400, 57600 and 115200 – default).

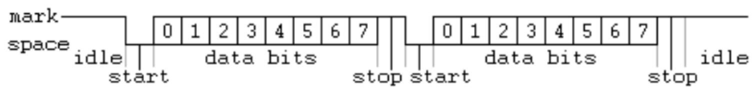


Figure 13: Serial protocol format

Each camera control register can be updated independently. In terms of the serial protocol, all registers are defined as 16-bit address (hex format) and 32-bit data (hex format). Camera registers using less than 32-bits in width must be padded with 0's on writes, and unused bits are ignored on reads. Register data is always "packed low" within 32-bit data words for registers defined by less than 32-bits.

There is a latency delay for each command due to command execution and data transmission over the serial port. This latency varies from command to command because of resource location and command response length.

3.2.2.1 Write Operation

To write to any given camera register, a sequence of 7 bytes should be sent to the camera. If there is no error, the camera returns one byte acknowledge for the write command <Ack> (Figure 14). If there is an error the camera returns two bytes not-acknowledge for the write command – the first byte is <Nac> <Err>, the second is the error code (Figure 15 and Figure 16):

Write to camera (7 Bytes): <Write_Cmd> <Address> <Data>

1st byte: 0x57 (Write Command)
2nd byte: <Register Address_High> MSB
3rd byte: <Register Address_Low> LSB
4th byte: <Register Data Byte 4> MSB
5th byte: <Register Data Byte 3> …
6th byte: <Register Data Byte 2> …
7th byte: <Register Data Byte 1> LSB
Write Acknowledge (1 Byte): <Ack>

1st byte: 0x06 (Acknowledge)

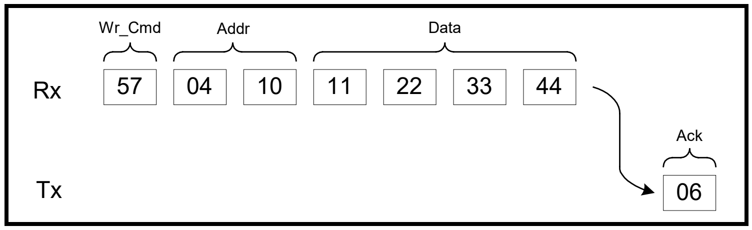


Figure 14: Normal write cycle

Write Not-acknowledge (2 Bytes): <Nac> <Error Code>

1st byte: 0x15 (Not-acknowledge)
2nd byte: <XX> (Nac Error Code. See 3.2.2.3 Error Code Description section)

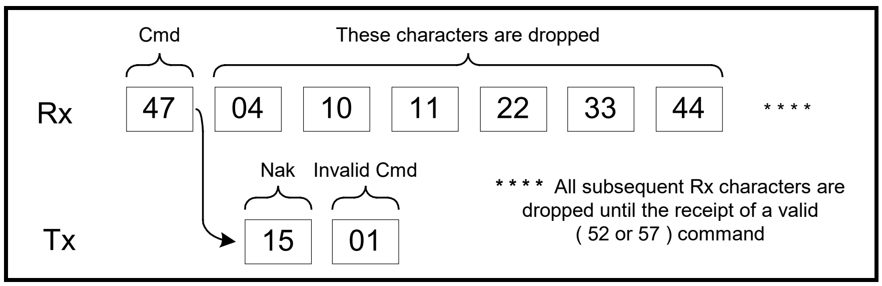


Figure 15: Invalid command error

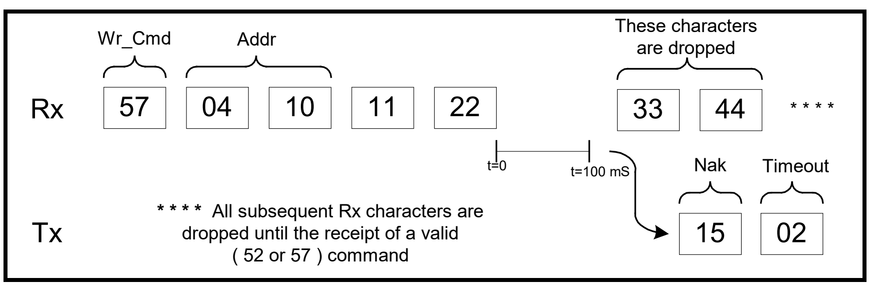


Figure 16: Rx timeout error

Example: Write to register address 0x0410, data value = 0x11223344:

Camera Write Command: **<0x57> <04> <10> <11> <22> <33> <44>**

3.2.2.2 Read Operation

To read from any given camera register, a sequence of 3 bytes should be sent to the camera. If there is no error, the camera returns 5 bytes – a one byte acknowledge for the read command <Ack> and four bytes of data <DD> <DD> <DD> <DD>. During read operation, the camera does not return an error or <Nac>. The only exception is the case of invalid command.

If you specify a wrong address, the camera returns acknowledge <06> and four bytes of data **<00> <00> <00> <00>.**

Read from camera (3 Bytes) : <Read_Cmd> <Address>
1st byte: 0x52 (Read Command)
2nd byte: <Register Address_High> MSB
3rd byte: <Register Address_Low> LSB

The camera returns (5 bytes): <ACK> <Data>
1st byte: 0x06 (Acknowledge)
2nd byte: <Register Data Byte 4> MSB
3rd byte: <Register Data Byte 3> …
5th byte: <Register Data Byte 2> …
6th byte: <Register Data Byte 1> LSB

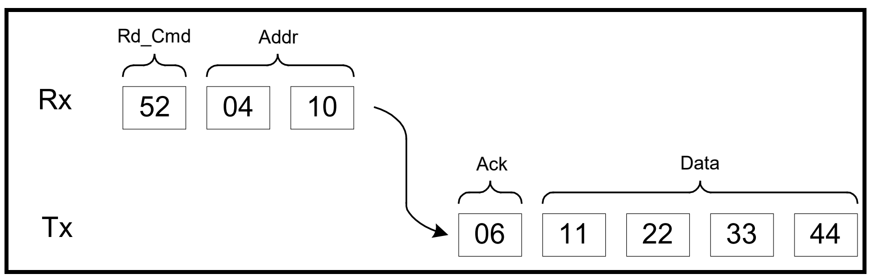


Figure 17: Normal read cycle

Example: Read from camera register address 0x0410:

\Camera Read Command: **<0x52> <04> <10>**

Camera returns register data payload value 0x11223344:

Register data **<0x06> <11> <22> <33> <44>**

3.2.2.3 Error Code Description

To manage camera reliability, not-acknowledge error codes are defined as follows:

x00 – No error
x01 – Invalid command. An invalid command (not 52 or 57) has been sent to the camera.
x02 – Time-out.
x03 – Checksum error
x04 – Value less then minimum
x05 – Value higher than maximum
x06 – AGC error
x07 – Supervisor mode error
x08 – Mode not supported error

3.3 Camera Configuration Register Descriptions

3.3.1 Startup Procedure

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 FPGA.
2. The camera reads the 'Boot From' register from the parameter FLASH and loads its workspace from one of the configuration spaces as determined by the 'Boot From' data. The available configuration spaces are: 'Factory…', 'User #1…', 'User #2…'.
3. The camera is initialized and ready to accept user commands.

3.3.2 Saving and Restoring Settings

Operational settings for the camera may be stored for later retrieval in its non-volatile memory. Three separate configuration spaces exist for storing these settings: 'Factory' space, 'User #1' space and 'User #2' space.

The factory space is pre-programmed by factory personnel during the manufacturing process. This space is write protected and cannot be altered by the user.

Two user spaces are also provided allowing you to store your own preferences. You can command the camera to load its internal workspace from any of the three configuration spaces at any time. You can also define configuration space the camera should automatically load itself following a power cycle or receipt of a reset (`'SW_Reset'`) command.

3.3.2.1 Boot From

This register determines the configuration space (Factory, User#1 or User #2) to load into the camera following a power cycle or reset (`'SW_Reset'`) command. Upon a power cycle or reset, the camera reads the 'Boot from' value from non-volatile memory and loads the appropriate configuration space.

Address	:	0x6000
Data (1:0)	:	0x0 – Boot from Factory
		0x1 – Boot from User #1
		0x2 – Boot from User #2
Data (31:2)	:	N/A

3.3.2.2 Load From Factory

The `'Load From Factory'` command instructs the camera to load its workspace from the factory space. All current workspace settings will be replaced with the contents of the factory space. This is a command, not a register. The act of writing to this location initiates the load from the factory.

Address	:	0x6060

3.3.2.3 Load From User #1

The 'Load From User #1' command instructs the camera to load its workspace from the User #1 space. All current workspace settings will be replaced with the contents of the User #1 space. This is a command, not a register. The act of writing to this location initiates the load from the User #1.
Address : 0x6064

3.3.2.4 Load From User #2

The 'Load From User #2' command instructs the camera to load its workspace from the User #2 space. All current workspace settings will be replaced with the contents of the User #2 space. This is a command, not a register. The act of writing to this location initiates the load from the User #2.
Address : 0x6068

3.3.2.5 Save to User #1

The 'Save To User #1' command instructs the camera to save its workspace to the User #1 space. All current workspace settings will be saved to the User #1 space. This is a command, not a register. The act of writing to this location initiates the save to User #1 space.
Address : 0x6074

3.3.2.6 Save to User #2

The 'Save To User #2' command instructs the camera to save its workspace to the User #2 space. All current workspace settings will be saved to the User #2 space. This is a command, not a register. The act of writing to this location initiates the save to User #2 space.
Address : 0x6078

3.3.2.7 Software Reset

The 'SW_Reset' command instructs the camera to initiate software reset, which resets the camera and loads its workspace from one of the configuration spaces as determined by the 'Boot From' data. Although, this is a command, the user MUST write a specific data 0xDEADBEEF in order to initiate the reset sequence.
Address : 0x601C
Data : 0xDEADBEEF

3.3.3 Retrieving Manufacturing Data

The camera contains non-volatile memory that stores manufacturing related information. This information is programmed in the factory during the manufacturing process.

3.3.3.1 Firmware Revision

This register returns the camera main firmware revision.
Address : 0x6004
Data (31:28) : <FW image>
Data (27:24) : <Camera type: 0xB – mono or ENIR, 0xC – color>
Data (23:0) : <FW revision>

3.3.3.2 Firmware Build Number

This register returns the firmware build number, which tracks custom firmware for specific applications.

Address	:	0x6038
Data	:	<value> - Firmware Build Number

3.3.3.3 Assembly Part Number

This register returns the camera assembly part number – the complete assembly part number is 4 registers.

Address	:	0x7004, 0x7008, 0x700C, 0x7010
Data	:	<Assembly Part Number>

3.3.3.4 Camera Serial Number

This register returns the camera serial number – the complete serial number is 2 registers.

Address	:	0x7014, 0x7018
Data	:	<Camera Serial Number>

3.3.3.5 CMOS Serial Number

This register returns the CMOS imager number – the complete CMOS number is 2 registers.

Address	:	0x701C, 0x7020
Data	:	<CMOS Image Sensor Serial Number>

3.3.3.6 Date of Manufacture

This register returns the camera date of manufacture – The complete date of manufacture is 2 registers.

Address	:	0x7024, 0x7028
Data	:	<Date of Manufacture>

3.3.3.7 Camera ID Type

This register shows the camera type.

Address	:	0x603C
Data (1:0)	:	10 – Cheetah Python (25M, 16M, 12M, 10M)
Data (31:2)	:	<N/A>

3.3.4 Camera Information Registers

The camera has a set of information registers, which provide information for the camera current status, frame rate, exposure time, image size, etc.

3.3.4.1 Current Horizontal Frame Size

This register returns the current horizontal image frame size in pixels.

Address	:	0x6090
Data (12:0)	:	<Current Horizontal Size>
Data (31:13)	:	<N/A>

3.3.4.2 Current Vertical Frame Size

This register returns the current vertical image frame size in lines.

Address	:	0x6094
Data (12:0)	:	<Current Vertical Size>
Data (31:13)	:	<N/A>

3.3.4.3 Current Frame Time

This register returns the current frame time in µs.

Address	:	0x6084
Data (23:0)	:	<Frame Time>
Data (31:24)	:	N/A

3.3.4.4 Minimum Frame Time

This register returns the minimum frame time in µs.

Address	:	0x608C
Data (23:0)	:	<Minimum Frame Time>
Data (31:24)	:	N/A

3.3.4.5 Current Pixel Clock Maximum

This register returns the current maximum pixel clock rate for line time control.

Address	:	0x60B0
Data (8:0)	:	<Maximum Pixel Clock Rate>
Data (31- 9)	:	N/A

3.3.4.6 Current Pixel Clock Rate

This register returns the current pixel clock rate for line time control.

Address	:	0x6020
Data (8:0)	:	<Pixel Clock Rate>
Data (31:9)	:	N/A

3.3.4.7 Current Exposure Time

This register returns the current camera exposure time in µs.

Address	:	0x6080
Data (23:0)	:	<Camera Exposure>
Data (31:24)	:	N/A

3.3.4.8 Maximum/Minimum Exposure Time

This register shows the maximum/minimum exposure time in µs.

Address	:	0x6088
Data (23:0)	:	<value> Maximum Exposure in µs
Data (31:24)	:	<value> Minimum Exposure in µs

3.3.4.9 Camera attributes

Shows information about the following functionality:

Address	:	0x60AC
Data (28:0)	:	Reserved
Data (29)	:	0x1 – PAOI is available, 0x0 - PAOI is not available
Data (30)	:	0x1 – AEC is available, 0x0 - AEC is not available
Data (31)	:	0x1 – AGC is available, 0x0 - AGC is not available

3.3.4.10 Current Gain & Luminance Status

The register returns the current gain and the current average image luminance during normal and AGC/AEC. It also returns flags when gain/exposure limits are reached during the AGC/AEC.

Address	:	0x60B8
Data (13:0)	:	<Current Gain >
Data (15, 14)	:	N/A
Data (27:16)	:	<Current Average Luminance>
Data (28)	:	0x0 – Gain Minimum Limit Not Reached 0x1 – Gain Minimum Limit Reached
Data (29)	:	0x0 – Gain Maximum Limit Not Reached 0x1 – Gain Maximum Limit Reached
Data (30)	:	0x0 – Exposure Minimum Limit Not Reached 0x1 – Exposure Minimum Limit Reached
Data (31)	:	0x0 – Exposure Maximum Limit Not Reached 0x1 – Exposure Maximum Limit Reached

3.3.4.11 Horizontal Image Size Maximum

This register returns the maximum horizontal image size in pixels.

Address	:	0x60A4
Data (15:0)	:	<Maximum Horizontal Size>
Data (31:16)	:	N/A

3.3.4.12 Vertical Image Size Maximum

This register returns the maximum vertical image size in pixels

Address	:	0x60A8
Data (12:0)	:	<Maximum Vertical Size>
Data (31:13)	:	N/A

3.3.4.13 Current Camera Temperature

This register returns the current camera temperature in degrees Celsius. The temperature resolution is 0.25 degrees Celsius – Table 16.

Address : 0x6010
Data (9:0) : <Current Camera Temperature>
Data (31:10) : N/A

Table 16: Current camera temperature values

Temperature	Register Value
+127.75 °C	01 1111 1111
...	...
+0.25 °C	00 0000 0001
0° C	00 0000 0000
-0.25 °C	11 1111 1111
...	...
-128 °C	10 0000 0000

3.3.5 AGC/AEC registers

3.3.5.1 Auto Exposure Control (AEC)

The register enables the auto exposure control.

Address : 0x0500
Data (0) : 0x0 – Disable auto exposure control
0x1 – Enable auto exposure control
Data (31:1) : N/A

3.3.5.2 AEC Maximum Exposure Time Limit

The register sets the maximum exposure time limit during AEC. The automatic exposure control process will keep the camera exposure always below the set level. This is to prevent motion smear.

Address : 0x0514
Data (19:0) : <value> – Maximum exposure time limit, µs
Data (31:20) : N/A

<value> MIN : "AEC Minimum Exposure Time Limit 0x0510" register + 1
<value> MAX : "Maximum Exposure Time Limit 0x6088" register
<value> STEP : 1 µs

3.3.5.3 AEC Minimum Exposure Time Limit

The register sets the minimum exposure time limit during AEC. The automatic exposure control process will keep the camera exposure always below the set level. This is to prevent motion smear.

Address : 0x0510
Data (19:0) : <value> – Minimum exposure time limit, µs
Data (31:20) : N/A

<value> MIN : 4 µs
<value> MAX : "AEC Maximum Exposure Time Limit 0x0514" register - 1
<value> STEP : 1 µs

3.3.5.4 Auto Gain Control (AGC)

The register enables the auto gain control.

Address	:	0x0504
Data (0)	:	0x0 – Disable auto gain control
		0x1 – Enable auto gain control
Data (31:1)	:	N/A

3.3.5.5 Maximum Gain Limit

The register sets the maximum analog gain limit during AGC. The automatic gain control process will keep the camera analog gain always below the set level.

Address	:	0x051C
Data (13:0)	:	<value> – Maximum analog gain limit
Data (31:14)	:	N/A
<value> MIN	:	"Minimum Gain Limit 0x0518" register + 1
<value> MAX	:	16383 (15.9x)
<value> STEP	:	1 (0.00097x)

3.3.5.6 Minimum Gain Limit

The register sets the minimum analog gain limit during AGC. The automatic gain control process will keep the camera analog gain always below the set level.

Address	:	0x0518
Data (13:0)	:	<value> – Minimum analog gain limit
Data (31:14)	:	N/A
<value> MIN	:	1024 (1x)
<value> MAX	:	"Maximum Gain Limit 0x051C" register - 1
<value> STEP	:	1 (0.00097x)

3.3.5.7 Luminance Level Threshold

The register sets the desired luminance level to be maintained during AEC or AGC process.

Address	:	0x050C
Data (11:0)	:	<value> – Desired luminance level
Data (31:12)	:	N/A
<value> MIN	:	1
<value> MAX	:	4095
<value> STEP	:	1

3.3.5.8 Luminance Type Selection

The register sets the luminance mode to be used during AEC or AGC process. The correction algorithm can use the average luminance for the entire frame or the peak luminance in the frame.

Address	:	0x0508
Data (1:0)	:	0x0 – Average luminance
		0x1 – Peak luminance
		0x2 or 0x3 – Reserved
Data (31:2)	:	N/A

3.3.5.9 Exposure and Gain Correction Speed

This register sets the exposure and gain correction speed during AEC/AGC. The automatic exposure and gain control processes can set the algorithm convergence speed, i.e. how long it takes to reach the desired exposure or gain.

Address	:	0x0520
Data (1:0)	:	0x0 – 1x speed – Slowest
		0x1 – 2x speed
		0x2 – 3x speed
		0x3 – 4x speed – Fastest
Data (31:2)	:	N/A

3.3.6 Exposure Control

This register controls the Exposure Control.

Address	:	0x0720
Data (1:0)	:	0x0 – Off (Free Running)
		0x1 – Trigger Pulse Width (Duration of selected trigger pulse determines exposure time)
		0x2 – Internal (Exposure Time register sets exposure time in microseconds)
		0x3 – Reserved
Data (31:2)	:	N/A

3.3.7 Exposure Time (Internal)

This register sets the exposure time when the “Internal” exposure mode is selected.

Address	:	0x0728
Data (19:0)	:	<value> – Actual exposure in microseconds
Data (31:20)	:	N/A

<value> MIN	:	0 µs
<value> MAX	:	1 s
<value> STEP	:	1 µs

3.3.8 Programmable Frame Period Enable

This register enables the Fixed Frame Period.

Address	:	0x0700
Data (0)	:	0x0 – Disable
		0x1 – Enable
Data (31:1)	:	N/A

3.3.9 Output Pixel Clock Rate and Zero ROT

3.3.9.1 Pixel Clock Rate

This register sets the Pixel Clock Rate in MHz for the output.

Address	:	0x0404
Data (8:0)	:	<value> in MHz (32 to value in Pixel Clock Max register)
Data (31:9)	:	N/A
<value> MIN	:	32 MHz
<value> MAX	:	"Current Pixel Clock Maximum 0x60B0" register
<value> STEP	:	1 MHz

3.3.9.2 Zero Row Overhead Time (Zero-ROT)

This register controls Row Overhead Time. When disabled, one microsecond is added to each line time. In CL two tap mode, Zero-ROT must be disabled.

Address	:	0x0708
Data (0)	:	0x0 – Disable Zero-ROT 0x1 – Enable
Data (31:1)	:	N/A

3.3.10 Fixed Frame Period

This register sets the frame period.

Address	:	0x0704
Data (19:0)	:	<value> – Frame period in microseconds
Data (31:20)	:	N/A
<value> MIN	:	"Minimum Frame Time 0x608C" register
<value> MAX	:	1 s
<value> STEP	:	1 µs

3.3.11 Area of Interest

These set of registers defines the Area of Interest (AOI) and sets the appropriate window size and offset in horizontal and vertical direction.

3.3.11.1 AOI Horizontal Offset

This register sets the AOI horizontal offset in pixels.

Address	:	0x0008
Data (11:0)	:	<value> – AOI horizontal offset (multiple of 8)
Data (31:12)	:	N/A
<value> MIN	:	0
<value> MAX	:	"Maximum horizontal image size 0x60A4" register - 8
<value> STEP	:	8

3.3.11.2 AOI Horizontal Size

This register sets the AOI horizontal size in pixels.

Address	:	0x000C
Data (12:0)	:	<value> – AOI horizontal size (multiple of 8)
Data (31:13)	:	N/A
<value> MIN	:	8
<value> MAX	:	"Maximum horizontal image size 0x60A4" register
<value> STEP	:	8

3.3.11.3 AOI Vertical Offset

This register sets the AOI vertical offset in pixels.

Address	:	0x0000
Data (11:0)	:	<value> – AOI vertical offset (multiple of 2)
Data (31:12)	:	N/A
<value> MIN	:	0
<value> MAX	:	"Maximum vertical image 0x60A8" register - 2
<value> STEP	:	2

3.3.11.4 AOI Vertical Size

This register sets the AOI vertical size in pixels.

Address	:	0x0004
Data (11:0)	:	<value> – AOI vertical size (multiple of 2)
Data (31:12)	:	N/A
<value> MIN	:	2
<value> MAX	:	"Maximum vertical image size 0x60A8" register
<value> STEP	:	2

3.3.12 Processing AOI Control

The Processing AOI (PAOI) control is introduced to support the AGC/AEC functionality. It allows you to select AOI for luminance calculation. Also, it could be used for AWB and LUT.

3.3.12.1 PAOI Enable

Address	:	0x0020
Data (3:0)	:	0x0 – PAOI disable
		0x1 – PAOI include
		0x2 – PAOI exclude
		0x3 – PAOI for AEC/AGC include
		0x4 – PAOI for AEC/AGC exclude
		0x5 – PAOI for AWB include
		0x6 – PAOI for AWB exclude
		0x7 – PAOI for LUT include
		0x8 – PAOI for LUT exclude
Data (31:4)	:	N/A

3.3.12.2 PAOI Horizontal Offset

This register sets the PAOI horizontal offset in pixels.

Address	:	0x0018
Data (12:0)	:	<value> – PAOI offset in horizontal direction
Data (31:13)	:	N/A
<value> MIN	:	0
<value> MAX	:	“Maximum Horizontal Size 0x60A4” - “PAOI Horizontal Size 0x001C” - 8
<value> STEP	:	8

3.3.12.3 PAOI Horizontal Size

This register sets the PAOI horizontal size in pixels.

Address	:	0x001C
Data (12:0)	:	<value> – PAOI horizontal size
Data (31:13)	:	N/A
<value> MIN	:	“PAOI Horizontal Offset 0x0018” + 8
<value> MAX	:	“Maximum Horizontal Size 0x60A4”
<value> STEP	:	8

3.3.12.4 PAOI Vertical Offset

This register sets the PAOI vertical offset in pixels.

Address	:	0x0010
Data (12:0)	:	<value> – PAOI offset in vertical direction
Data (31:13)	:	N/A
<value> MIN	:	0
<value> MAX	:	“Maximum Vertical Size 0x60A8” - “PAOI Vertical Size 0x0014” - 2
<value> STEP	:	2

3.3.12.5 PAOI Vertical Size

This register sets the PAOI vertical size in pixels.

Address	:	0x0014
Data (12:0)	:	<value> – PAOI vertical size
Data (31:13)	:	N/A
<value> MIN	:	“PAOI Vertical Offset 0x0010” + 2
<value> MAX	:	“Maximum Vertical Size 0x60A8”
<value> STEP	:	2

3.3.13 Decimation (Averaging or Subsampling)

3.3.13.1 Subsampling Mode

This register controls subsampling.

Address	:	0x073C
Data (1:0)	:	0x0 – Subsampling off
		0x1 – Subsampling in x
		0x2 – Subsampling in y
		0x3 – Subsampling in x & y
Data (31:2)		N/A

3.3.13.2 Averaging Mode

This register controls Averaging.

Address	:	0x0754
Data (1:0)	:	0x0 – averaging off
		0x1 – Averaging in x
		0x2 – Averaging in y
		0x3 – Averaging in x & y
Data (31:2)	:	N/A

3.3.14 Black Level auto-calibration

This register sets the Black Level auto-calibration mode.

Address	:	0x0758
Data (0)	:	0x0 – Disable Auto-calibration
		0x1 – Enable Auto-calibration
Data (31:1)	:	N/A

3.3.15 Black Level Offset

The Black Level Offset is added or subtracted from each pixel value only when auto-calibration dark level is disabled.

Address	:	0x075C
Data (8:0)	:	<value> – Black Level
Data (9)	:	<sign – if '0', then Black Level value is added to each pixel. If '1', then the Black Level value is subtracted>
Data (31:10)	:	N/A
<value> MIN	:	-512
<value> MAX	:	+511
<value> STEP	:	1

3.3.16 Analog and Digital Gain

3.3.16.1 Analog Gain

This register sets the Analog Gain.

Address : 0x0748

This register sets the Analog Gain.

Address	:	0x0748
Data (1:0)	:	0x0 – Analog Gain 1.0x
		0x1 – Analog Gain 1.26x
		0x2 – Analog Gain 1.87x
		0x3 – Analog Gain 3.17x
Data (31:2)	:	N/A

3.3.16.2 Digital Gain

This register sets Digital Gain.

Address : 0x0438

Data (13:0) : <value> – Codes 0 to 1023 are not used,
1024 to 16383 applies digital gain at 0.00097x per step

Data (31:14) : N/A

3.3.16.3 Digital Offset

This register sets Digital Offset.

Address : 0x043C

Data (9:0) : <Value> – Signed, -512 to +511 (leading '0'= '+' and '1' = '-')

Data (31:10) : N/A

3.3.17 Triggering Workspace Registers

3.3.17.1 Trigger Input Selector

This register selects the triggering source.

Address : 0x0650

Data (2:0) : 0x0 – IN1 – the camera expects the trigger to come from the external source mapped to the IN1 connection within the power and I/O connector.
0x1 – IN2– the camera expects the trigger to come from the external source mapped to the IN2 connection within the power and I/O connector.
0x2 – CC1 – the camera expects the trigger to come from the Camera Link cable signal CC1
0x3 – CC2 – the camera expects the trigger to come from the Camera Link cable signal CC2.
0x4 – Internal – the camera expects the trigger to come from the programmable pulse generator.
0x5 – Software trigger – the camera expects a computer to send a command `'Start SW Trigger'` to the camera for generating one short trigger pulse (see **Software Trigger Start** command). The trigger exposure is internal register controlled. Pulse duration exposure is not supported.
0x6 to 0x7 – N/A

Data (31:3) : N/A

3.3.17.2 Trigger Enable

This register enables or disables the triggering operation.

Address : 0x0654

Data (0) : 0x0 – Trigger is disabled, free running mode
0x1 – Trigger is enabled, camera is in trigger mode

Data (31:1) : N/A

3.3.17.3 Software Trigger Start

The 'Start SW Trigger' command instructs the camera to generate one short trigger pulse. This is a command, not a register. The act of writing to this location initiates the pulse generation.

Address	:	0x6030

3.3.17.4 Triggering Edge Selector

This register selects the triggering edge – Rising or Falling.

Address	:	0x0658
Data (0)	:	0x0 – Rising edge
		0x1 – Falling edge
Data (31:1)	:	N/A

3.3.17.5 Trigger De-bounce Time

This register selects the trigger signal de-bounce time. Any subsequent trigger signals coming to the camera within the de-bounce time interval will be ignored.

Address	:	0x065C
Data (2:0)	:	0x0 – No de-bounce
		0x4 – 10 μs de-bounce time
		0x5 – 50 μs de-bounce time
		0x1 – 100 μs de-bounce time
		0x6 – 500 μs de-bounce time
		0x2 – 1.0 ms de-bounce time
		0x7 – 5.0 ms de-bounce time
		0x3 – 10.0 ms de-bounce time
Data (31:3)	:	N/A

3.3.17.6 Trigger Exposure Delay

The register allows to delay start of exposure from active trigger edge

Address	:	0x0660
Data (23:0)	:	<value> – Trigger exposure delay in microseconds
Data (31:24)	:	N/A
<value> MIN	:	0
<value> MAX	:	1 s
<value> STEP	:	1 μs

3.3.17.7 Ignore Next Trigger

The register allows camera to ignore the next trigger during read-out time (simulates standard trigger mode).

Address	:	0x0664
Data (0)	:	0x0 – Accept next trigger during read-out
		0x1 – Ignore next trigger during read-out
Data (31:1)	:	N/A

3.3.18 Strobe Control Registers

These registers enable and control the position and pulse width of the two available strobes. The strobe signal is mapped to one or both of the available strobe outputs.

3.3.18.1 Strobe 1 Enable

This register enables Strobe 1.

Address	:	0x0630
Data (0)	:	0x0 – Disable
		0x1 – Enable
Data (31:1)	:	N/A

3.3.18.2 Strobe 1 Reference Select

This register sets the reference for the strobe 1 Start.

Address	:	0x0634
Data (0)	:	0x0 – Exposure Start
		0x1 – Readout Start
Data (31:1)	:	N/A

3.3.18.3 Strobe 1 Delay

This register sets the strobe 1 delay from the selected Reference.

Address	:	0x0638
Data (19:0)	:	<value> – Strobe 1 delay in microseconds
Data (31:20)	:	N/A
<value> MIN	:	0
<value> MAX	:	1 s
<value> STEP	:	1 μs

3.3.18.4 Strobe 1 Width

This register sets the strobe 1 pulse duration.

Address	:	0x063C
Data (19:0)	:	<value> – Strobe 1 width in microseconds
Data (31:20)	:	N/A
<value> MIN	:	0
<value> MAX	:	1 s
<value> STEP	:	1 μs

3.3.18.5 Strobe 2 Enable

This register enables Strobe 2

Address	:	0x0640
Data (0)	:	0x0 – Disable
		0x1 – Enable
Data (31:1)	:	N/A

3.3.18.6 Strobe 2 Reference Select

This register sets the reference for the strobe 2 start.

Address	:	0x0644
Data (0)	:	0x0 – Exposure Start
		0x1 – Readout Start
Data (31:1)	:	N/A

3.3.18.7 Strobe 2 Delay

This register sets the strobe 2 delay from the selected Reference

Address	:	0x0648
Data (19:0)	:	<value> – Strobe 2 delay in microseconds
Data (31:20)	:	N/A
<value> MIN	:	0
<value> MAX	:	1 s
<value> STEP	:	1 µs

3.3.18.8 Strobe 2 Width

This register sets the strobe 2 pulse duration.

Address	:	0x064C
Data (19:0)	:	<value> – Strobe 2 width in microseconds
Data (31:20)	:	N/A
<value> MIN	:	0
<value> MAX	:	1 s
<value> STEP	:	1 µs

3.3.19 Pulse Generator Registers

3.3.19.1 Pulse Generator Timing Granularity

This register sets the pulse generator main timing resolution. The main resolution is in microseconds, and 4 granularity steps are possible – x1, x10, x100, x1000 (x1000 is equal to 1 ms timing resolution).

Address	:	0x0690
Data (1:0)	:	0x0 – x1
		0x1 – x10
		0x2 – x100
		0x3 – x1000
Data (31:2)	:	N/A

3.3.19.2 Pulse Generator Pulse Width

This register sets the value of the pulse width in microseconds.

Address	:	0x0694
Data (18:0)	:	<value> – Pulse width in microseconds
Data (31:19)	:	N/A

3.3.19.3 Pulse Generator Pulse Period

This register sets the value of the pulse period in microseconds.

Address	:	0x0698
Data (19:0)	:	<value> – Pulse width in microseconds
Data (31:20)	:	N/A

3.3.19.4 Pulse Generator Number of Pulses

This register sets the number of the pulses generated when the Pulse Generator Mode is set to Burst Mode (discrete number of pulses)

Address	:	0x069C
Data (15:0)	:	<value> – Number of discrete pulses
Data (31:16)	:	N/A

<value> MIN	:	1
<value> MAX	:	65535
<value> STEP	:	1

3.3.19.5 Pulse Generator Mode

This register sets the Pulse Generator to either continuous mode or burst mode.

Address	:	0x06A4
Data (0)	:	0x0 – Continuous Mode - continuous pulse generation 0x1 – Burst Mode - Generate discrete number of pulses (see Pulse Generator Number of Pulses section, register 0x069C)
Data (31:1)	:	N/A

3.3.19.6 Pulse Generator Enable

This register enables the pulse generator.

Address	:	0x06A0
Data (0)	:	0x0 – Disable pulse generator operation 0x1 – Enable pulse generator operation
Data (31:1)	:	N/A

3.3.20 Test Pattern Workspace Registers

3.3.20.1 Test Mode Select

This register selects the test mode pattern.

Address	:	0x0428
Data (3:0)	:	0x0 – No test pattern 0x1 – Steady horizontal image ramp 0x2 – Steady vertical image ramp 0x3 – Moving horizontal image ramp 0x4 – Moving vertical image ramp 0x5 – Crosshairs superimposed over live image 0x6 and 0x7 – Reserved
Data (31:4)	:	N/A

3.3.21 Input/output Workspace Registers

3.3.21.1 OUT1 Output Polarity

This register sets the polarity (active Low or High) for the OUT1 output.

Address	:	0x0680
Data (0)	:	0x0 – Active LOW
		0x1 – Active HIGH
Data (31:1)	:	N/A

3.3.21.2 OUT1 Output Mapping

This register maps the various internal signals to OUT1 camera output.

Address	:	0x0684
Data (2:0)	:	0x0 – No mapping
		0x1 – Trigger pulse
		0x2 – Pulse generator
		0x3 – Strobe 1
		0x4 – Strobe 2
		0x5, 0x6, 0x7 – Reserved
Data (31:3)	:	N/A

3.3.21.3 OUT2 Output Polarity

This register sets the polarity (active Low or High) for the OUT2 output.

Address	:	0x0688
Data (0)	:	0x0 – Active LOW
		0x1 – Active HIGH
Data (31:1)	:	N/A

3.3.21.4 OUT2 Output Mapping

This register maps the various internal signals to OUT2 camera output.

Address	:	0x068C
Data (2:0)	:	0x0 – No mapping
		0x1 – Trigger pulse
		0x2 – Pulse generator
		0x3 – Strobe 1
		0x4 – Strobe 2
		0x5, 0x6, 0x7 – Reserved
Data (31:3)	:	N/A

3.3.22 Data Output Format Registers

3.3.22.1 Output Bit Depth

This register selects the bit depth output for the camera.

Address	:	0x040C
Data (0)	:	0x0 – 8-bit
	:	0x1 – 10-bit
Data (31:1)	:	N/A

3.3.22.2 Data Format Selector

This register selects the tap format for the camera data output.

Address	:	0x0424
Data (2:0)	:	0x0 – N/A
		0x1 – 2 tap interleaved
		0x2 – 4 tap interleaved
		0x3 – 8 tap interleaved
		0x4 – 10 tap interleaved
		0x5, 0x6, 0x7 – reserved
Data (31:2)	:	N/A

3.3.23 White Balance (WB) Workspace Registers

3.3.23.1 WB Select

This register selects which white balance mode will be used – Off, Once, Auto or Manual.

Address	:	0x0538
Data (0:2)	:	0x0 – Off
		0x1 – WB Once
		0x2 – WB Auto Tracking
		0x3 – WB Manual
		0x4 to 0x7 – Reserved
Data (31:3)	:	N/A

3.3.23.2 Automatic White Balance (AWB) tracking

The camera will automatically track the scene and adjust white balance according to five different tracking rates.

Address	:	0x053C
Data (0:2)	:	0x0 – 1x slowest
		0x1 – 2x
		0x2 – 3x
		0x3 – 4x
		0x4 – 5x fastest (no tracking)
		0x5 to 0x7 – unused
Data (31:12)	:	N/A

3.3.23.3 WBC Red Coefficient

This register contains the white balance correction coefficients for Red. In manual mode, the user enters the value, in once or Auto, the camera returns the actual (calculated) coefficient. Coefficient values range from 0.000 (0 Hex) to +15.996 (FFF Hex) in steps of 0.004 (4096 steps).

Address	:	0x0540
Data (11:0)	:	<value> – WBC Red
Data (31:12)	:	N/A

3.3.23.4 WBC Green Coefficient

This register contains the white balance correction coefficients for Green. In manual mode, the user enters the value, in Once or Auto, the camera returns the actual (calculated) coefficient. Coefficient values range from 0.000 (0 Hex) to +15.996 (FFF Hex) in steps of 0.004 (4096 steps).

Address	:	0x0544
Data (11:0)	:	<value> – WBC Green
Data (31:12)	:	N/A

3.3.23.5 WBC Blue Coefficient

This register contains the white balance correction coefficients for Blue. In manual mode, the user enters the value, in Once or Auto, the camera returns the actual (calculated) coefficient. Coefficient values range from 0.000 (0 Hex) to +15.996 (FFF Hex) in steps of 0.004 (4096 steps).

Address	:	0x0548
Data (11:0)	:	<value> – WBC Blue
Data (31:12)	:	N/A

3.3.24 Data Correction Workspace Registers

3.3.24.1 LUT Select

This register selects which LUT will be used – LUT1 or LUT2.

Address	:	0x0410
Data (0)	:	0x0 – LUT #1 selected
		0x1 – LUT #2 selected
Data (31:1)	:	N/A

3.3.24.2 LUT Enable

This register enables the selected LUT.

Address	:	0x0414
Data (0)	:	0x0 – Disable
		0x1 – Enable
Data (31:1)	:	N/A

3.3.24.3 Defective Pixel Correction (DPC) Enable

This register enables the DPC (Defective Pixel Correction).

Address	:	0x0418
Data (1:0)	:	0x0 – DPC disable
		0x1 – Static DPC
		0x2 – Dynamic DPC
		0x3 – Static and Dynamic DPC
Data (31:2)	:	N/A

3.3.24.4 HPC Enable

This register enables the HPC (Hot Pixel Correction).

Address	:	0x041C
Data (1:0)	:	0x0 – HPC disable
		0x1 – Static HPC
		0x2 – Dynamic HPC
		0x3 – Static and Dynamic HPC
Data (31:2)	:	N/A

3.3.24.5 Dynamic DPC Threshold

This register sets the threshold for dynamic defective pixel correction

Address	:	0x042C
Data (11:0)	:	<value> – 0 to 4095 counts
Data (31:12)	:	N/A

3.3.24.6 Dynamic HPC Threshold

This register sets the threshold for dynamic hot pixel correction

Address	:	0x0430
Data (11:0)	:	<value> – 0 to 4095 counts
Data (31:12)	:	N/A

3.3.25 Flat Field Correction and FPN Correction

3.3.25.1 Flat Field Correction Enable

This Register enables Flat Field Correction

Address	:	0x0420
Data (0)	:	0x0 – Disable
		0x1 – Enable
Data (31:1)	:	N/A

3.3.25.2 Flat Field Correction

This Register selects either the Factory default FFC or the User's custom FFC.

Address	:	0x0434
Data (0)	:	0x0 – FFC Factory
		0x1 – FFC User
Data (31:1)	:	N/A

3.3.25.3 FPN Correction

This register disables column Fixed Pattern Noise Correction allowing the user to implement a custom FPN solution.

Address	:	0x0440
Data (0)	:	0x0 – Disable
		0x1 – Enable
Data (31:1)	:	N/A

4 Software Configuration GUI

4.1 Camera Configurator Overview

Camera configuration utility software and the Cheetah camera configurator (CamConfig) are provided with each camera. After installing the program, you can program the camera, change settings, and save the settings in a file or in the camera. The configuration utility includes an interactive help file that helps guide you through the camera setup.

4.2 Installing the GUI

The USB flash drive included with your camera contains the camera configuration software for your Cheetah camera. The software is compatible with Microsoft Windows, 32-bit and 64-bit operating systems: Windows 7, Windows 8, and Windows 10.

Before Installing the Configuration Software:

1. Insert the USB flash drive in your computer.
2. Open File Explorer and locate the flash drive.
3. Double click the flash drive.
4. Drag and drop one of the following file to your desktop: Cheetah_CL_x_x_x.exe for Camera Link cameras.

NOTE

If an older version of the configuration software is on your computer, you must remove it. The software installation process will do this for you, or you can remove the software before beginning the installation. To remove the software before installation, open Control Panel on your computer, select Programs and Features, and select uninstall for Cheetah Camera Link.

Installing the Software:

- Double click the file that you transferred to your desktop (Cheetah_CL_x_x_x.exe).
- When the Open File screen appears, click **Run**.
- After the Welcome screen appears, click **Next**.
- Click **I Agree** to accept the license terms.
- Follow the on-screen instructions until complete.
- Reboot your computer. A shortcut icon will appear on your desktop.

Troubleshooting CamConfig Configuration Software Installation:

If the CamConfig software does not find your computer's COM ports, you might need to locate your frame grabber's DLL file and move it to C:\Windows\System32. You can search File Explorer for the DLL file by entering clser* in the search field. Note: your frame grabber's vendor name abbreviation should appear where XXX is shown in the clserXXX.dll file name.

4.3 Camera Discovery Procedure

The CamConfig utility provides an intelligent, automated method of searching and discovering all available UART components in your PC and allowing you to select the one connected to the Cheetah camera. This is important because often times multiple frame grabbers and cameras are installed in a computer. The CamConfig utility expects to find the serial interface `DLL clserXXX.dll` file in C:\\Windows\System32. The search engine finds not only the CamLink DLL port but also looks for any available COM port installed on the PCl. It will then communicate with each port (.DLL and COM) and attempt to query the attached camera. If it finds an attached Imperx Cheetah camera, it will read the camera type information from the camera. The camera name will appear in the list box, which includes all DLLs, ports, and cameras discovered. You can then select the DLL, port or camera of interest by highlighting the entry and clicking OK. Clicking the Rescan Ports button causes the above discovery procedure to be repeated. Note, the frame grabber has to be Camera Link v1.0 (or later) compliant.

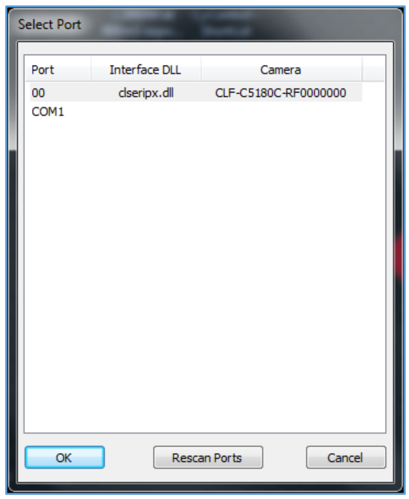


Figure 18: Select a camera

TIP

If the CamConfig software does not find your camera, it could be because your frame grabber stored the clserXXX.dll file in a different directory on your computer. You will need to locate the file and move it to C:\Windows\System32.

To search for the frame grabber's clserXXX.dll file:

1. In Windows File Explore, click the **C drive**.
2. In the search field type **clser*** and press **Enter**.
3. After finding the appropriate file, move it to C:\Windows\System32.

4.4 Graphical User Interface

After selecting the desired camera, the main Cheetah CamConfig dialog appears (Figure 19). The Graphical User Interface (GUI) is intuitive and self-explanatory. The basic features are:

- **Compact Design** – small size saves space when user displays image and control at the same time.
- **Real Time Data** – updates camera information in real time while camera is working. Gives quick and general information about camera configuration status.
- **Dockable Windows** – all configuration windows (Gain, AOI, Trigger . . .) can be separated and “docked” in the main GUI with just one click.
- **Configurable** – you can customize the main menu by selecting the sub windows and also memorize the last setting.

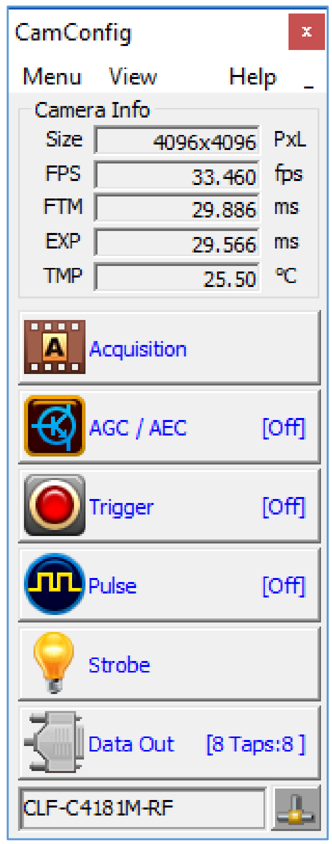


Figure 19: CamConfig GUI

On the main window, you can see useful camera information – Current Image Size (Size), Number of Frame per second (FPS), the Frame Time (FTM), Exposure Time (EXP) and Temperature of the CMOS sensor (TMP). Additional information can be obtained by clicking on the buttons shown in the CamConfig window, such as Acquisition, Trigger, Pulse etc. The bottom of the main utility window is camera name and status of Cam-link connection. If the connection between the camera and the computer is lost, a red cross will appear above the connection icon.

4.5 Main GUI Menu

The Menu provides access to load options, settings, the command terminal, and more (Figure 20).

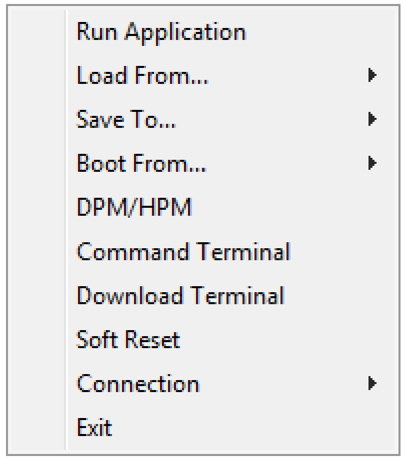


Figure 20: Main Menu

Run Application
Starts other executable files (frame grabber application, etc.). CamConfig remembers the path to the last executable file you used, so you can start the application without having to type-in the location.

Load From…
Loads the camera registers from a saved configuration space: File, Workspace, Factory Space, User Space #1 or User Space #2.

- **File** – loads the camera registers from a saved configuration file.
- **Workspace** – updates the software with the current camera workspace settings.
- **Factory** – loads the camera registers with the original (factory) settings.
- **User Space #1** – loads the camera registers with camera settings saved in the User space 1.
- **User Space #2** – loads the camera registers with camera settings saved in the User space 2.

Save To…
Saves the camera registers to file, User Space #1 or User Space #2. Factory Space is disabled for regular users and it is available only for manufacturing technicians.

- **File** – saves the current camera settings to a configuration file.
- **Factory Space** – saves the current camera settings to the camera Factory space. This is restricted command and is disabled for regular users.
- **User Space #1** – saves the current camera settings to the camera User space 1.
- **User Space #2** – saves the current camera settings to the camera User space 2.

Boot From…
This menu selects the Boot From source. Upon power up, the camera will load its registers from the selected 'Boot From' source: Factory, User #1 or User #2. Cheetah camera will be release with 'Factory" Setting and user can save and boot camera with their own configurable features.

DPM/HPM

When selected, the Defect Pixel Map window shows defective or hot pixels location (Figure 21). The maps are stored in the camera's non-volatile memory and read out when running defective or hot pixel correction.

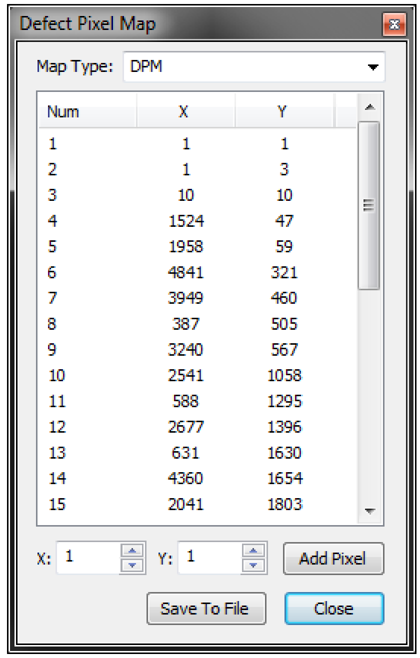


Figure 21: Defective pixel map

- **Map type** – selects what type of defect pixel map to show:
  - **DPM (Defective Pixel Map)** – a map of pixels with sensitivity that deviates more than 15% due to fluctuations in the CMOS manufacturing process.
  - **HPM (Hot Pixel Map)** – a map of pixels that during normal camera operation are normal, but in long integration modes (programmable frame time) behave as high-intensity bright pixels.
- **Add Pixel** – you can add a defective or hot pixel into DPM or HPM by entering its location (see section 9.3.3 Locating and adding pixel coordinates, **STEP 4**)
  - **X and Y** – horizontal and vertical coordinates of the defective pixel.
- **Save To File** – saves the map shown in Defect Pixel Map window into a .dmp or .hpm file.

TIP

If you are adding more than one defective pixel into DPM or HPM, we recommend to do the following steps:

1. Save a map that you want to add pixels to on your computer by clicking on **Save to File**. The file will have extension .dpm or .hpm.
2. Open the file using any standard ASCII text editor, Microsoft Notepad, or Microsoft Excel.
3. Add defective pixels, save changes and close the file (see section 9 Creating DPC / HPC Tables for more information).

4. Select **Menu** > **Download Terminal** on GUI.
5. Click **File Type** and select a file **DPM** or **HPM**.
6. Enter or browse to the location of the file that you saved in step 3.
7. Select the file you want to download.
8. Click **Load File**.
   Reboot the camera and restart the GUI for the changes to take into effect.

Command Terminal

Shows information about all commands sent to or received by the camera. It also lets you communicate directly with the camera by entering write or read commands directly into the text box on the Command Terminal screen.

To write a command to a camera register, the command terminal must send a sequence of 7 bytes to the camera. The write command must start with 0x followed by 57, the register address, and data.

Example:
Write to register address 0x0410, data value = 0x11223344:
Camera Write Command: <0x57> <04> <10> <11> <22> <33> <44>

To read a command from a camera register, the command terminal must send a sequence of 3 bytes to the camera. The read command must start with 0x followed by 52 and the register address.

Example:
Read from register address 0x0410:
Camera Read Command: <0x52> <04> <10>

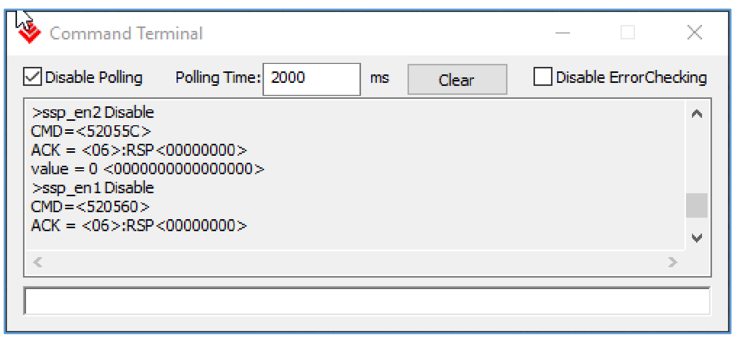


Figure 22: Command Terminal command to addresses 055C and register 0560

- **Disable Polling** check box turns polling commands on or off for frame time, exposure time, frame rate, and so on.
- **Polling Time** – You can change the polling time in milliseconds by entering a number in the Polling Time field.
- **Disable Error Checking** – The software displays error messages when the camera returns a command error. You can disable error checking by selecting the Disable Error Checking check box.

Download Terminal

The Download Terminal (Figure 23) lets you upgrade the camera's firmware and upload any custom files — DPM, HPM, Flat Field Correction (FFC), Lookup Tables (LUT), or Register Set (RGS).

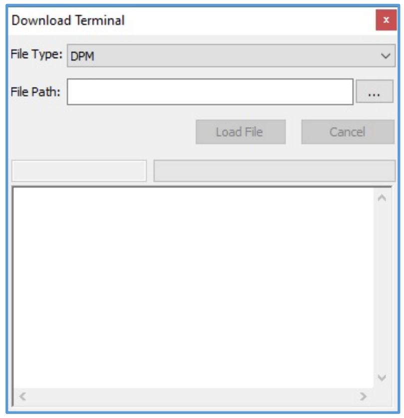


Figure 23: Download Terminal

To download files to the camera:

1. Click **File Type** and select a file type such as DPM, HPM, FFC, RGS, or LUT1/LUT2.
2. Enter or browse to the location of the file on your computer.
3. Select the file you want to download.
4. Click **Load File**.

Reboot the camera and restart the GUI for the changes to take into effect.

Soft Reset

Re-initializes the camera similar to cycling power to the camera.

Connection

Use the Connection menu to switch ports and change baud rates.

- **Switch Port** – If checked, "Select Port" window pops up. The user can select new Camera Link port, which connect to current camera. Use this option to switch the com port/camera. You can also Rescan Ports before switching
- **Set Baud Rate** – use this to change the speed of data transmission. A higher baud rate number indicates the transfer of more bits per second. Baud rates are 9600, 19200, 28400, 57600, and 115200. The factory default is 115200.

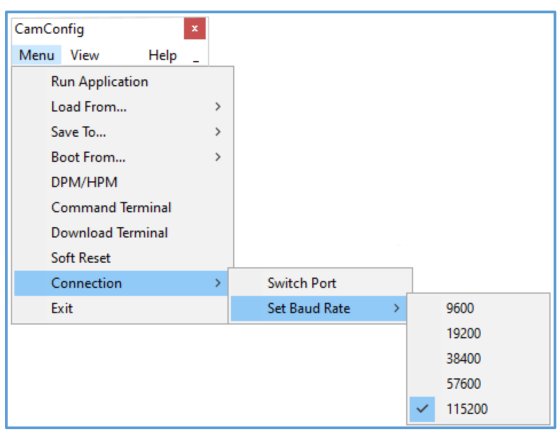


Figure 24: Connection menu

Exit

Terminates the application.

4.6 View GUI Windows

Use the View menu to display or hide the following panels: Acquisition, AGC/AEC, Trigger, Pulse, Strobe, Color, and Data Out on the screen.

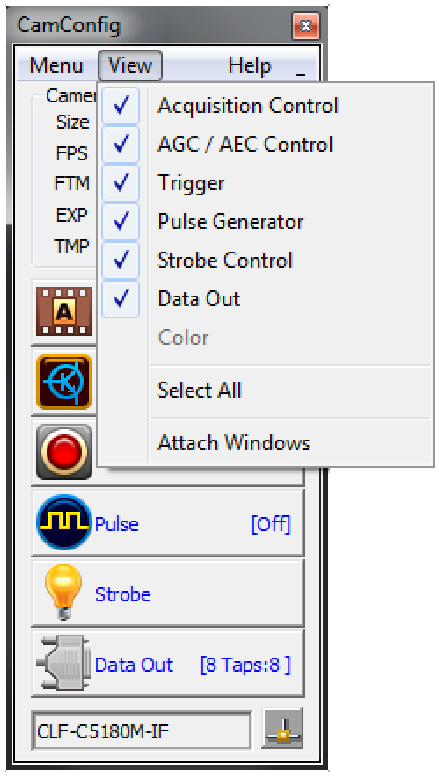


Figure 25: View Menu

Acquisition Control
Controls the exposure time, frame period, pixel clock rate, AOI, analog and digital gain, black level, averaging, subsampling).

AGC/AEC Control
Maintains consistent image brightness during times of fluctuating lighting conditions. You can enable both automatic exposure mode and automatic gain mode simultaneously.

Trigger
Controls the camera triggering features.

Pulse Generator
Enables and controls the internal pulse generator which can be used to generate trigger or output signals.

Strobe Control
Enables and controls the camera strobe signals.

Data Output
Sets the output data format, enables Look-Up Tables, DPC, HPC, and test patterns.

Color
Sets the white balance mode. Displays WBC values.

Select All
Enables all camera parameter windows.

Attach Windows
Attaches all camera parameter windows to the main GUI window
Select All: Enables all camera parameter windows.

Attach Windows: Attaches all camera parameter windows to the main GUI window.

4.7 Menu Help

Help provides access to a user help file and the following options (Figure 26).

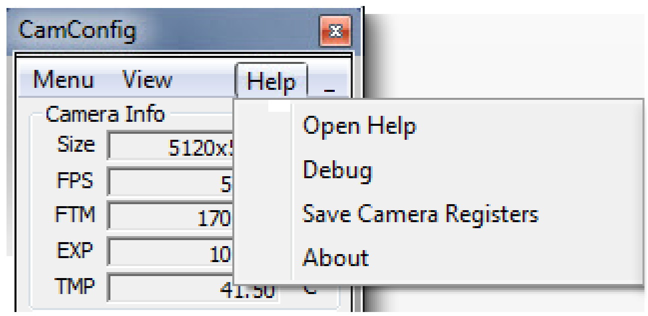


Figure 26: Help menu

Open Help
Opens an interactive help file.

Debug
Puts the GUI in a debug mode for test purposes and troubleshooting.

Save Camera Registers
Saves the camera registers to a file.

About
Provides information about application version and important camera parameters such as Firmware revision, Assembly Part Number, and so on.

4.8 Parameter Windows

Cheetah Cameras have many features that can easily be programmed using the Cheetah graphical user interface (GUI) or via simple register commands using the Command Terminal. The main parameter windows are described below.

4.8.1 Acquisition Control Panel

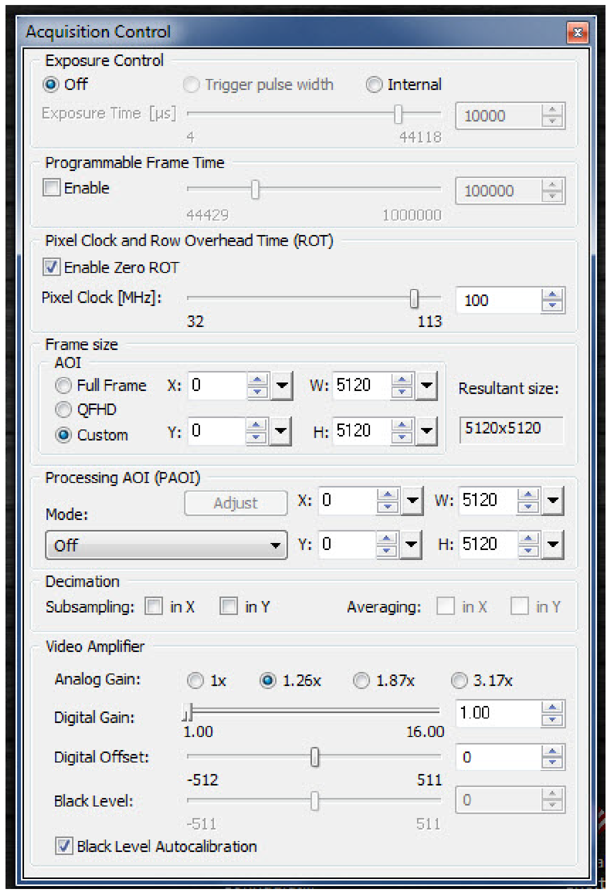


Figure 27: Acquisition Control Panel

4.8.1.1 Exposure, Frame Time, Pixel Clock and ROT Controls

This window (**Figure 28**) controls the camera exposure, frame time, pixel clock rate, and row overhead time (ROT).

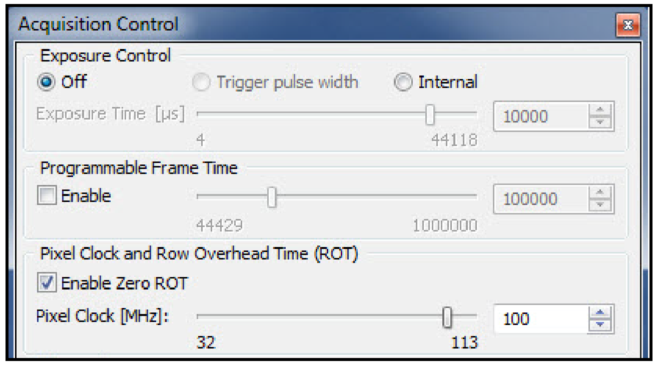


Figure 28: Exposure control window

4.8.1.1.1 Exposure Control

Sets the camera exposure period with three options:

Off – no exposure control. The camera free runs, and the exposure time equals the frame time.

Trigger Pulse Width – Sets the exposure time equal to the trigger's input pulse width. Trigger must be enabled (see 4.8.2 Trigger Panel section).

Internal – enables the internal camera registers to control the exposure. After selecting Internal, use the **Exposure Time** slider to set the actual camera exposure in microseconds or enter the desired exposure time in the box to the right of the slider. The maximum exposure time adjusts accordingly, based on the camera frame time.

4.8.1.1.2 Frame Time, Pixel Clock and ROT Controls

These controls allow you to control the frame rate and the line rates of the camera. Since the camera outputs data at a very high rate, you can use Pixel Clock Rate and Zero ROT to match the camera output rate to the interface bandwidth. The Programmable Frame Time control should be enabled to achieve the desired output frame rate.

Programmable Frame Time – This is the time required to read out the entire frame. Select the check box to enable Frame Time control. When enabled, you can set the frame time using the slider bar or by entering the desired frame time in the box to the right of the slider (up to 1000000 microseconds (1 s)).

Pixel Clock Rate – determines the Line Readout Rate. Decreasing the Pixel Clock Rate increases the time to read out a line.
Zero-ROT – Unchecking Zero-ROT control increases the line readout time by one microsecond. As a general rule, you should check Zero-ROT unless prompted by the camera to uncheck it. In CL two tap mode, Zero-ROT MUST be unchecked.

4.8.1.2 Area of Interest (AOI)

Use AOI to select the area of the image sensor to output. You can choose to output the entire image sensor field of view or any region within this field of view.

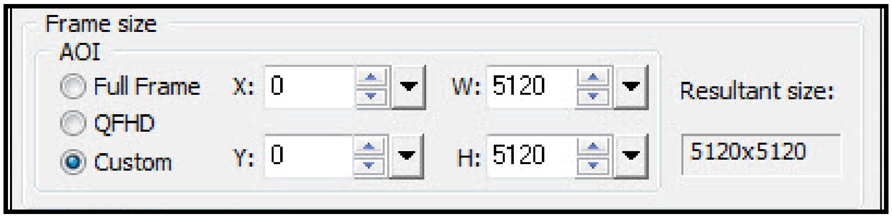


Figure 29: AOI Functions

Full Frame – This is a pre-programmed AOI providing the full resolution of the camera.

QFHD – This is a pre-programmed AOI providing a Quad Full HD (3840 x 2160) frame size centered within the field of view.

Custom – This lets you enter the desired area of interest by setting the active window size (Width, Height) and offset (X, Y). Image location (1, 1) is top left corner. You can set the desired window size by entering the numbers directly or by using the scroll controls. Horizontal offset and width values MUST be a multiple of 8.

4.8.1.3 Processing AOI (PAOI)

All Areas of Interest (AOI) are functionally equal except PAOI. A PAOI can be enabled as a LUT or image processing Area of Interest or as other modes. When enabled as a processing AOI, the selected processing function (LUT or AWB) will apply only to the selected AOI, all data outside of the region will not be processed with the selected function. When enabled as AEC/AGC processing AOI, AEC/AGC will use luminance calculated only for the selected AOI and then be applied to the full image.

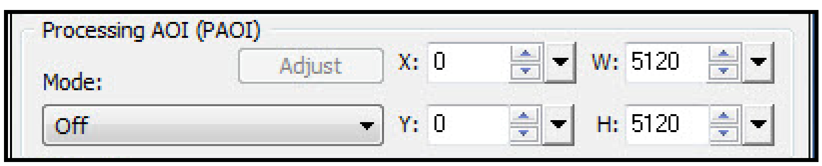


Figure 30: Processing AOI

You can adjust the boundaries of the PAOI and select a mode from the following drop-down options:

- **Off** – turns off PAOI.
- **Use for image** – processes only the dimensions applied to the PAOI.
- **Excl. for image** – processes the area outside of the dimensions applied to the PAOI.
- **Use for AGC/AEC processing** – luminance calculated inside the selected PAOI.
- **Excl. for AGC/AEC processing** – luminance calculated outside the selected PAOI
- **Use for AWB processing** – applies auto white balance settings to the PAOI.
- **Excl. for AWB processing** – disables applied auto white balance settings.
- **Use for LUT processing** – applies the LUT settings you selected on the Data Output screen to the PAOI.
- **Excl. for LUT processing** – disables applied LUT settings.

4.8.1.4 Subsampling and Averaging

Subsampling and Averaging functions are active within the defined AOI and is used to reduce the output resolution while maintaining the desired field of view.

Figure 31: Subsampling Functions

Subsampling – Decimates the output image within the defined AOI using a “keep one pixel, skip one pixel” sequence for monochrome cameras and ‘keep two pixels, skip two pixels’ for Bayer color cameras. Checking the ‘in X’ box, discards every other pixel within a (horizontal) line. Checking the ‘in Y’ box discards every other line (vertically) within the frame.

Averaging – The Cheetah offers a four-into-one (4:1) averaging function for monochrome cameras only. Checking ‘in X’ averages two adjacent pixels within a line to produce a single pixel result. Checking ‘in Y’ averages two pixels within the same column to produce a single pixel result. Checking both ‘in X’ and ‘in Y’ averages four pixels within a 2x2 ROI to produce a single pixel result.

4.8.1.5 Video Amplifier

The Video Amplifier allows you to adjust the Analog and Digital Gains and black level. Manual entry and sliders are available for adjusting the individual parameters.

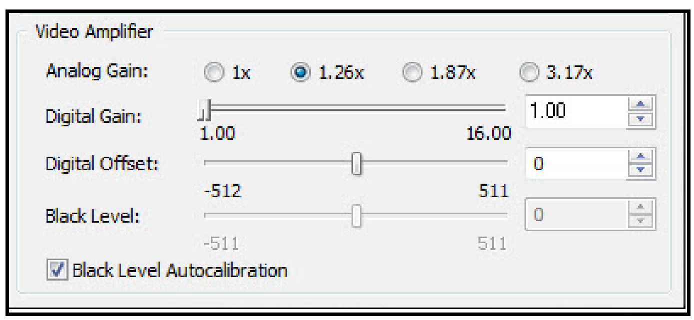


Figure 32: Video Amp Parameter Menu

Analog Gain – You can set the desired analog gain using radio buttons. Analog gain levels of 1x, 1.26x, 1.87x and 3.17x.can be selected.

Digital Gain – You can set the digital gain from 1 to 15.9x with 0.00097x per step.

Digital Offset – You can set the offset via 1024 steps (-512 to +511 steps).

Black Level – Black Level Auto-Calibration should always be selected. Unchecking Black Level Auto-calibration allows you to vary the black level from -511 to +511 counts, but the black level will vary with gain settings if Black Level Autocalibration is unchecked.

4.8.2 Trigger Panel

Use the Trigger tab to set the camera trigger inputs and trigger settings. You can select from one of six input sources and set the active trigger edge to rising or falling with optional signal de-bouncing.

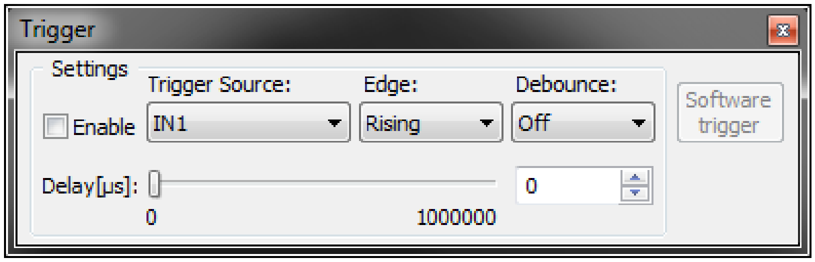


Figure 33: Trigger parameter Menu

Enable – Allows you to control start of image capture with the trigger source.

Trigger Source –Select the active triggering input signal from one of the following six sources:

- **IN1** – the camera expects the trigger to come from the external source mapped to the IN1 connection within the power and I/O connector.
- **IN2** – the camera expects the trigger to come from the external source mapped to the IN2 connection within the power and I/O connector.
- **CC1** –the camera expects the trigger to come from the Camera Link cable signal CC1.
- **CC2** –the camera expects the trigger to come from the Camera Link cable signal CC2.
- **Internal** – the camera expects the trigger to come from the programmable pulse generator.
- **Software Trigger** – Provides a software button that triggers the camera one time. This can be useful in a debugging operation. The button becomes active only when the trigger source is set to Software.

Edge – Selects the active triggering edge of the trigger pulse:

- **Rising** – Uses the rising edge of the trigger pulse to start the exposure.
- **Falling** – Uses the falling edge of the trigger pulse to start the exposure.

De-bounce – The trigger inputs are de-bounced to prevent multiple triggering from ringing triggering pulses. The camera provides the following eight choices of de-bounce interval:

- **Off** – No de-bounce
- **10.0** us – 10 microseconds de-bounce interval.
- **50.0** us – 50 microseconds de-bounce interval.
- **100.0** us – 100 microseconds de-bounce interval (default).
- **500.0** us – 500 microseconds de-bounce interval.
- **1.0** ms – 1 milliseconds de-bounce interval.
- **5.0** ms – 5 milliseconds de-bounce interval.
- **10.0** ms – 10 milliseconds de-bounce interval.

Delay – Sets the delay between the trigger pulse active edge and beginning of the exposure. You can set the delay from 0 to 1000000 microseconds.

4.8.3 Pulse Generator Panel

In this panel, you can configure the parameters of the Internal Pulse Generator.

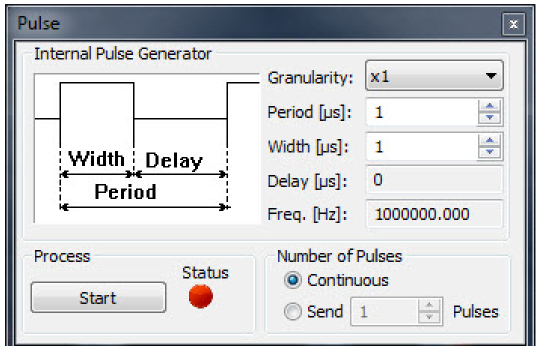


Figure 34: Pulse Generator Panel

Granularity – Sets the granularity for the internal counters. Granularity can be set to 1x, 10x, 100x or 1000x.

Period – Sets the pulse period in microseconds.

Width – Sets the pulse width in microseconds.

Process: Starts and stops the process of Internal Pulse Generator. When the process is in progress, the **Start** button becomes a **Stop** button.

Status (provides the status of the process):

- – the process is on hold,
- – the process is working.

Number of Pulses – Sets the number of pulses generated. Two modes are available:

- **Continuous** – provides a continuous operation. To stop the process, you have to press the Stop button.
- **Send # Pulses** – you can set a discrete number of pulses ranging from 1 to 65500 to be generated. To stop the process, you must press the Stop button. Otherwise, the process stops automatically after the last pulse is sent.

4.8.4 Strobe Control and Output Mapping

The Strobe Control panel lets you configure camera strobe signals. The camera supports two independently controlled strobe signals.

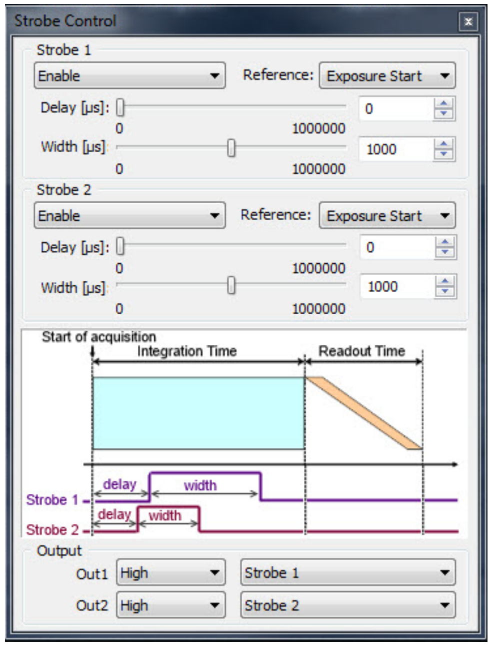


Figure 35: Strobe Control Panel

Strobe 1 – Sets the Strobe 1 mode of operation. The strobe can be disabled or enabled.

Strobe 2 – Sets the Strobe 2 mode of operation. The strobe can be disabled or enabled.

Reference – Sets the reference for the Strobe pulse. Options are either the Start of the exposure period or the Beginning of the readout period.
Delay/Width – Sets the duration and delay of the strobe sent to the camera output. The user can set the strobe pulse width and the delay from 0 to 1000000 microseconds.

4.8.4.1.1 Output Mapping

The Output section enables mapping the camera's two outputs (Out1 and Out2) to internal output signals. For each output, you can set signal level to active High or Low.
The following internal output signals are available for mapping:

Table 17: Output Mapping

Output Signals	Description
Trigger Input	Maps the input trigger pulse to the output with no delay (as is).
Pulse Generator	Maps the internal pulse generator waveform to the output.
Strobe #1	Maps the Strobe 1 signal to the corresponding external output.
Strobe #2	Maps the Strobe 2 signal to the corresponding external output.

Out1 Polarity – External Output 1 polarity can be changed to be active High or Low.

Out2 Polarity – External Output 2 polarity can be changed to be active High or Low

4.8.5 AGC / AEC Control

Use the AGC/AEC controls to maintain consistent image gain/brightness during changing lighting conditions.

You can enable Automatic Gain Control (AGC) and Automatic Exposure Control (AEC) independently or simultaneously. Auto gain and auto exposure controls let you place minimum and maximum limits on auto gain/exposure.

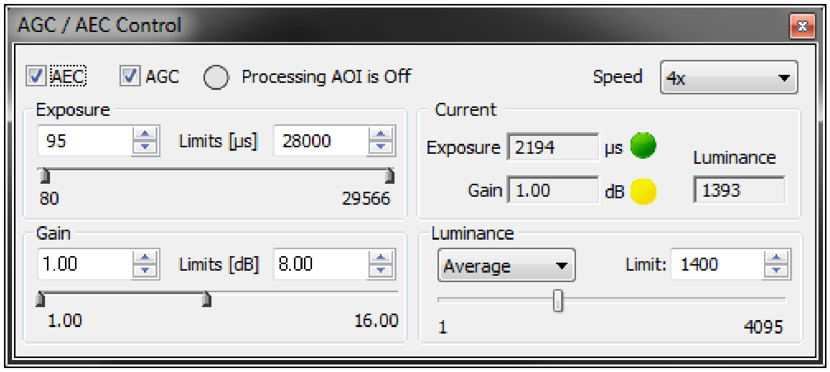


Figure 36: AGC/AEC Controls

AEC – Select the check box to enable automatic exposure control. The camera will constantly adjust the exposure to achieve a preset luminance target.

AGC – Select the check box to enable automatic gain control. The camera will constantly adjust gain to achieve a preset luminance target.
Processing AOI is Off – Provides the status of the PAOI (refer to the section **Error! Reference source not found. Error! Reference source not found.**). If Processing AOI is ON, the indicator shows one of the PAOI's modes:

- – PAOI is enabled as **Use for AGC/AEC processing** (luminance is calculated inside the PAOI).
- – PAOI is enabled as **Excl. for AGC/AEC processing** (luminance is calculated outside the PAOI).

Speed – Sets the camera's exposure or gain correction speed during AEC/AGC. Speed can be set to 1x (slowest), 2x, 3x or 4x (fastest).

Exposure – Allows you to set the minimum and maximum exposure time target value in microseconds.

Gain – Allows you to set the minimum and maximum digital gain target value in decibels.

Current – Displays the camera's current exposure or digital gain values. Two indicators at the right provide status of the current exposure or gain:

- – the exposure/gain value is in the set limits.
- – the exposure/gain has reached minimum value.
- – the exposure/gain has reached maximum value.

Luminance – Allows you to set the target luminance as an average or peak brightness.

4.8.6 Data Output Control

The Data Output window provides full control of the camera digital data output.

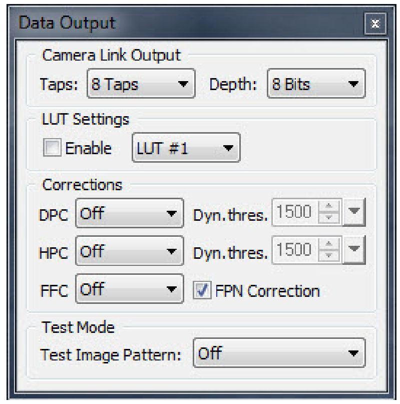


Figure 37: Data Output Panel

Camera Link Output – Sets the data format and camera speed. The greater the number of taps, the faster the pixel readout. For example, 8-tap Camera Link Full reads out faster than 4-tap Camera Link Medium.

- **Taps** – Sets the number of image taps used in the current configuration. Select from the following Camera Link Output Taps:
  - 2-Taps: Camera Link Base (24-bits)
  - 4-Taps: Camera Link Medium (48-bits)
  - 8-Taps: Camera Link Full (72-bits)
  - 10-Taps: Camera Link Deca (80-bits)
- **Depth** – Sets the output data bit depth, which is the number of output bits per pixel mapped to the camera link output. Options are 8 or 10 bits.

LUT Settings – You can modify original video data into other arbitrary values based on a preset lookup table (LUT). Place a check in the Enable check box and select a preset LUT from the LUT drop-down. By default, LUT #1 and LUT #2 are factory programmed with a standard Gamma of 0.45. You can reprogram LUT #1 and LUT #2 (see 8 Creating Look-up Tables).

Corrections – This section enables defective (defective or hot) pixel correction.

- **DPC** – Enables Defective Pixel Correction (DPC) and allows either static, dynamic, or both static and dynamic Defective pixel correction. Each camera comes with a built-in Defective Pixel Map (DPM) to correct for defective pixels. You can upload a custom DPM, if desired.
  - **Off** – Turns off Defective Pixel Correction.
  - **Static** – Corrects defective pixels using a preset Defective Pixel Map.
  - **Dynamic** – Identifies defective pixels dynamically on a frame-by-frame basis. Once identified, defective pixels are corrected on subsequent frames.
  - **Combined** – Corrects defective pixels based on a preset Defective Pixel Map and any additional defective pixels identified dynamically. Dynamic Pixel Correction data is not retained if the camera is power-cycled.

- **HPC** – Enables Hot Pixel Correction (HPC) and allows either static, dynamic, or both static and dynamic hot pixel correction. Each camera comes with a built-in Hot Pixel Map (DPM) to correct for hot pixels. The user can upload a custom HPM, if desired.
    - **Off** – Turns off Hot Pixel Correction.
    - **Static** – Corrects hot pixels using a preset Hot Pixel Map.
    - **Dynamic** – Identifies hot pixels dynamically based on a user defined threshold on a frame-by-frame basis. Once identified, hot pixels are corrected on subsequent frames.
    - **Combined** – Corrects hot pixels based on a preset Hot Pixel Map and any additional defective pixels identified dynamically. Dynamic Hot Pixel Correction data is not retained if the camera is power cycled.
- **Flat Field Correction** – Enables or disables flat field correction to improve non-uniformity in the image sensor. Recommendation: leave flat field correction on.
- **FPN Correction** – The camera can automatically correct for column fixed pattern (FPN) noise. Recommendation: leave FPN box checked.

Test Mode – The camera can output the following test patterns:

- **Off** – test mode is off.
- **H Ramp** – displays a stationary horizontal ramp image.
- **V Ramp** – displays a stationary vertical ramp image.
- **H Ramp move** – displays a moving horizontal ramp image.
- **V Ramp move –** displays a moving vertical ramp image.
- **Crosshair** – superimposes a cross, located in the center of the CMOS images.

4.8.7 Color Control

This screen sets the corrections for the primary red, green, blue (RGB) colors used by color camera models. In addition, you can select a white balance mode and view the calculated white balance coefficients. This feature is disabled for monochrome cameras.

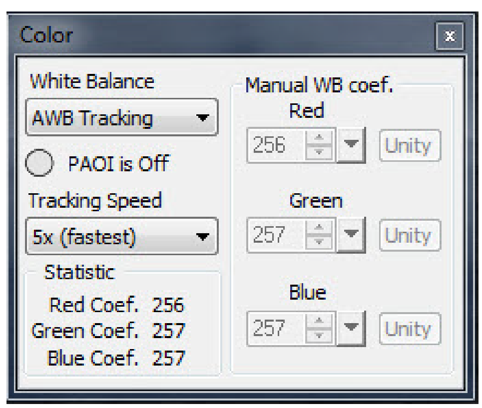


Figure 38: Color Panel

White Balance – Sets the White balance mode of operation.

- **Off** – No white balance is performed.
- **AWB Once** – The camera analyzes one image frame, calculates one set of correction coefficients, and corrects all subsequent frames this set of coefficients.
- **AWB Tracking** – The camera analyzes every frame, derives a set of correction coefficients for each frame, and applies them to the next frame.
- **Manual** – The camera uses the correction coefficients as entered from the user.

Manual WB coef. – You can manually set the white balance coefficients (digital gains) for each color. The range is from 0 to 4095 (0 is equal to 0.0x, 256 is equal to 1.0x, 4095 is equal 15.995x). You also have option to set all coefficients to zero or set all gains to "Unity" (1.0x).

Statistic – gives you the current (calculated) white balance coefficients per color.

TIP

To get the best white balance for the R, G, and B coefficients when the spectral source is constant:

1. Image a grey or white target over the camera's entire field of view using the intended lighting source.
2. Select **AWB Once** from the White Balance drop-down. Write down the values of R, G, and B coefficients from the **Statistic** area.
3. Change AWB Once to **Manual**.
4. Load the coefficients into the camera. Leave **Manual** selected. The camera will now apply these coefficients to every frame captured.

PAOI is Off – Provides the status of the PAOI (refer to the section **Error! Reference source not found. Error! Reference source not found.**). If Processing AOI is ON, the indicator shows one of the PAOI's modes:

- – PAOI is enabled as **Use for AWB processing** (auto white balance settings are applied to the PAOI).
- – PAOI is enabled as **Excl. for AWB processing –** (auto white balance settings are not applied to the PAOI).

Tracking Speed – For Auto-White Balance (AWB), you can select from five update rates. When 1x is selected, the AWB algorithm responds slowly to any changes in the scene illumination, whereas 5x tracking provides the fastest responsiveness.

5 Camera Features

5.1 Exposure Control

5.1.1 Internal Exposure Control - Electronic Shutter

In global shutter, all pixels in the array are reset at the same time, allowed to collect signal during the exposure time, and then transferred to a non-photosensitive region within each pixel. Once the image is transferred to the non-photosensitive region, the readout of the array begins. In this way, all pixels capture the image during the same time period, which reduces any image artifacts appearing due to motion within the scene. The maximum exposure is frame time dependent and the minimum exposure is about 40 microseconds.

The camera normally overlaps the exposure and readout times as shown in below.

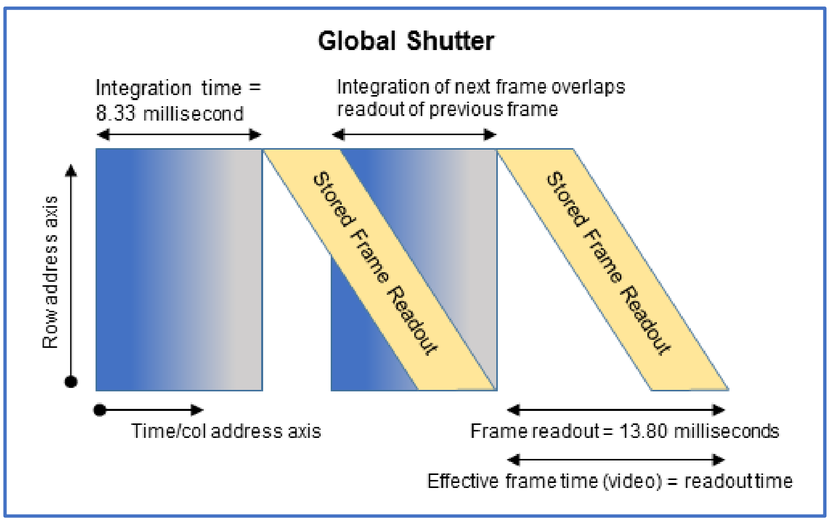


Figure 39: Global Shutter with 8.33mS exposure time

5.1.2 External Exposure Control

The camera can use an external pulse to control exposure. The pulse duration determines the exposure. In global shutter mode, the minimum exposure time is about 40 microseconds. Refer to section 5.5 Camera Triggering and 5.10 Input / Output Control.

5.2 Frame Time Control

5.2.1 Internal Line and Frame Time Control

The camera speed (frame rate) depends on the CMOS readout time. The readout time is the time needed to read all the pixels out of the CMOS imager. The frame rate can be calculated using the following Formula 1.1:

Frame rate [fps] = 1 / read-out time [sec] (1.1)

5.2.1.1 Pixel Clock Line Rate Control

You can use the Pixel Clock Rate function to program the camera's speed to match the Camera Link image capture rate.

You should never use Pixel Clock to control camera frame rate; for best image quality, you should always set the Pixel Clock to the maximum rate possible without the Camera Link interface missing or skipping data. This minimizes the dark current generated within the pixel and the dark current noise.

5.2.1.2 Programmable Frame Time Control

After adjusting the Pixel Clock to minimize the line readout time, you can increase the frame time using the programmable Frame Time function. When enabled, the sensor reads out the frame, then idles and inserts a vertical blanking period at the end of the frame readout to provide the desired frame rate.

In this way, you can match the camera's frame rate to application requirements. You can reduce the frame time to about one second with a precision of one microsecond. Using Frame Time control, you can achieve exposure times longer than the time needed to read out the image sensor.

5.2.2 Zero-Row Overhead (ROT) Control

A Row-Overhead time (ROT) control is provided and the control is called: "Zero-Row Overhead Time" (Zero-ROT). Disabling Zero-ROT adds one microsecond of blanking time at the end of each row to further reduce the line rate. Zero-ROT should only be used as a last resort and only when decreasing Pixel Clock line rate control to the minimum value still results in frame grabber overruns. Zero-ROT must always be disabled and is not supported when pixel averaging is used and when Camera Link Base output is selected.

TIP

If the exposure time is greater than 50 ms, the camera vibration must be kept to a minimum otherwise a motion induced smear will appear on the image.

5.2.3 Camera Output Control

Cheetah camera supports the following Camera Link Outputs: 2-Tap, 4-Tap, 8-Tap or 10-Tap Output. This corresponds to Base, Medium, Full or Deca Output. These camera settings combined with the output bit-depth (8 or 10-bit) to control the total the interface bandwidth. The output interface clock speed for the Cheetah Camera is 85-MHz (Camera Link Spec is 85 MHz maximum). It is important to match the camera's output to the frame grabber. Select a frame grabber or camera output based upon the following criteria of data rate:

Table 18: C5180 frame rates vs output taps

Camera	Bit Depth	Output	Data Rate (Gbit/s)	Full Resolution Frame Rate via Imperx VCE-CLPCIe04 (fps)	Full Resolution Frame Rate (fps)
C5180	8,10	2-Tap (Base)	2.04	6.4	6.4
	8,10	4-Tap (Medium)	4.08	12.8	12.8
	8-Bit	8-Tap (Full)	6.12	25.6	26
	10-Bit	8-Tap (Deca)	6.12	20.2	26
	8-Bit	10-Tap (Deca)	6.8	25.8	32

Table 19: C4181 frame rates vs output taps

Camera	Bit Depth	Output	Data Rate (Gbit/s)	Full Resolution Frame Rate via Imperx VCE-CLPCIe04 (fps)	Full Resolution Frame Rate (fps)
C4181	8,10	2-Tap (Base)	2.04	10	10
	8,10	4-Tap (Medium)	4.08	20	20
	8-Bit	8-Tap (Full)	5.44	39	40
	10-Bit	8-Tap (Deca)	6.8	31	40
	8-Bit	10-Tap (Deca)	6.8	39	50

Table 20: C4180 frame rates vs output taps

Camera	Bit Depth	Output	Data Rate (Gbit/s)	Full Resolution Frame Rate via Imperx VCE-CLPCIe04 (fps)	Full Resolution Frame Rate (fps)
C4180	8,10	2-Tap (Base)	2.04	14	14
	8,10	4-Tap (Medium)	4.08	26	26
	8-Bit	8-Tap (Full)	5.44	52	53
	10-Bit	8-Tap (Deca)	6.8	42	53
	8-Bit	10-Tap (Deca)	6.8	52	67

5.3 Area of Interest

5.3.1 Overview

For some applications, you may not need the entire image area, but only a portion of it. To accommodate this requirement, Cheetah provides one Area of Interest (AOI) (also known as Region of Interest or ROI). An AOI is a unique field of view created within the camera's maximum field of view. This limitation is based on the structure of the camera's sensor. When creating an AOI, you will specify its horizontal and vertical dimensions and location (using horizontal and vertical offsets).

5.3.2 Horizontal and Vertical Window

Set the starting and ending point for each AOI independently in the horizontal direction (Horizontal Window) and the vertical direction (Vertical Window) by setting the window (H & V) offset and (H & V) size, as shown in the following figure. 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, subsampling and averaging modes can be applied to the AOI to reduce the number of rows and columns output even further. Using the AOI function and subsampling / averaging modes effectively increase the camera frame rate. The maximum horizontal window size (H) and the vertical window size (V) are determined by image full resolution (For example, C5180: 5120 x 5120 or C4181: 4096 x 4096).

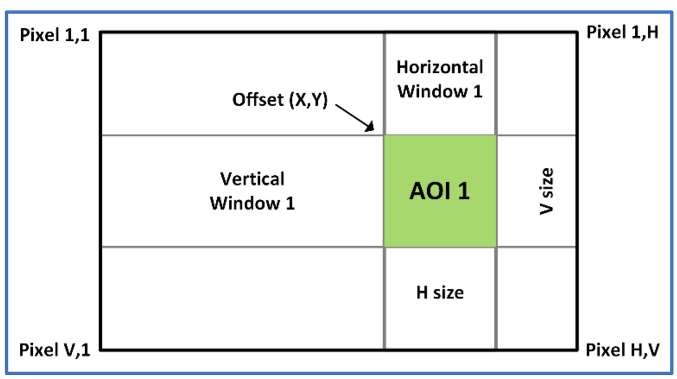


Figure 40: Horizontal and vertical window positioning

NOTE

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

5.3.3 Factors Impacting 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 – The camera frame rate will increase by decreasing either the number of columns or number of rows read out. Decreasing the number of rows to read out causes the largest increase 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 need 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 and subsampling increase the sensor frame rate. However, subsampling decimation offers the largest frame rate improvement by reducing the number of rows and columns read out from the image sensor. Sub-sampling and pixel averaging decimation provide about a 2x to 3x increase in frame rate.

Output Interface Bandwidth – The bandwidth of the output interface can also impact the maximum achievable frame rate. For example, with Camera Link Base (2 taps selected) and with 10-bit digitization and 10-bit output mode selected, the frame rate is limited by the output interface bandwidth of 2.04 Gbps.

5.3.3.1 AOI Frame Rate Examples

The following table provides resulting frame rates for various AOIs using Camera Link Deca output. The frame grabber speed will impact results (the values below assume an x8 speed frame grabber). The camera will calculate and display the actual frame rate at any horizontal and vertical window selection.
The following table provides examples of C5180 Frame Rate performance at full resolution and within selected AOIs.

Table 21: C5180 AOI frame rate for various AOIs

C5180 Frame Rates (fps)	8-bit, CL 10 Taps (fps)
Full Resolution	32
3840 x 2160	80
1920 x 1080	316
1280 x 720	570

5.4 Subsampling

5.4.1 Pixel Averaging

The principal objective of the averaging function is to reduce the image resolution with better final image quality than a subsampling function. Pixel averaging reduces the output resolution by averaging several pixels together and has the advantage of reducing aliasing and 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. The camera does not support Zero ROT when averaging is enabled. Color cameras do not support pixel averaging.

The following graphic illustrates the concept of 4:1 averaging for a monochrome image sensor. The values of pixels P1, P2, P3 and P4 are summed together and the result is divided by 4 to achieve an average of the 4 adjacent pixels.

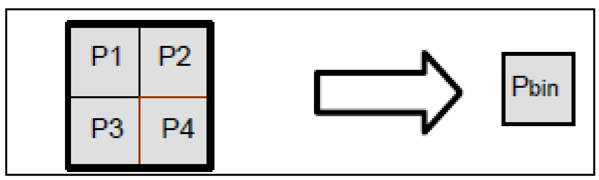


Figure 41: Monochrome pixel averaging

The averaging feature can be used 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)

5.4.2 Subsampling Decimation

Subsampling reduces the number of pixels output by reducing the output frame size but maintains the full field of view. If an area of interest (AOI) is selected, then the field of view of the AOI is maintained.

The C5180, C4181, and C4180 cameras employ a "keep one pixel, skip one pixel" sequence. When enabled in both x and y, every other pixel within a line is retained and every other line within the image is retained.

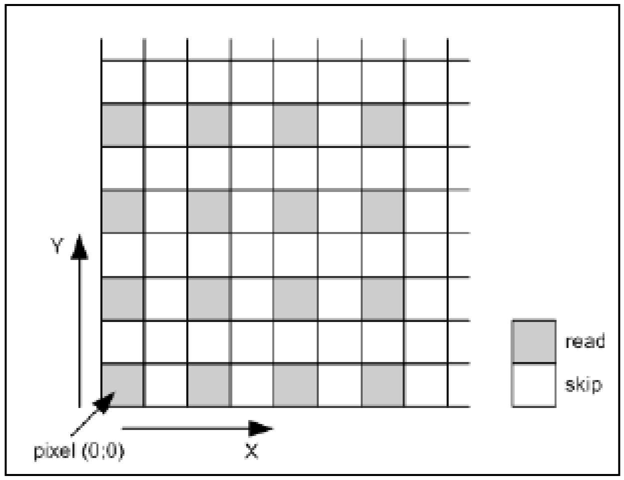


Figure 42: Monochrome subsampling

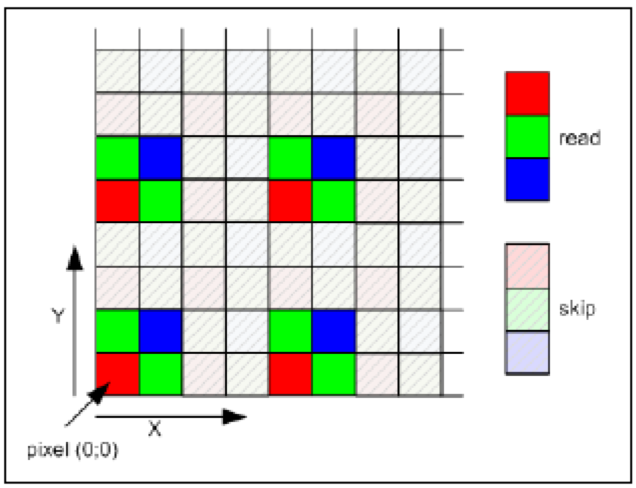


Figure 43: Color subsampling

5.5 Camera Triggering

5.5.1 Triggering Inputs

In the normal mode of operation, the camera is free running, which means the camera continually reads out the sensor. Using the trigger mode allows the camera to be synchronized to an external timing pulse.

There are four input modes available for external triggering: external, computer (CC), internal (pulse generator), and software. You must map the trigger input to a corresponding camera input.

External – the camera receives the trigger signal coming from the Hirose connector on the back of the camera.

Computer – the camera receives the trigger signal command from the CC signals.

Internal – the camera has a built-in programmable pulse generator (Figure 34). In Internal triggering mode, the camera receives the trigger signal from the internal pulse generator.

Software – the camera expects a computer to send a command to the camera for generating one short trigger pulse. You can trigger the camera by clicking the GUI Software Trigger button or by writing any data to address 0x6030. The trigger exposure is internal register controlled. Pulse duration exposure is not supported.

5.5.2 Acquisition and Exposure Control

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

Triggering Edge – select an active triggering edge.

- **Rising** – uses the rising edge for triggering
- **Falling** – uses the falling edge for triggering

De-bounce – the trigger inputs are de-bounced to prevent multiple triggering from ringing triggering pulses. Select from the following eight choices of de-bounce interval:

- **Off** – no de-bounce (default)
- **10 µs, 50 µs, 100 µs, 500 µs** de-bounce interval
- **1.0 ms, 5.0 ms, 10.0 ms** de-bounce interval

Exposure Time – Set the exposure for all frames in two ways.:

- **Pulse Width** – the trigger pulse width (duration) determines the exposure subject to limitations.
- **Internal** – the camera internal exposure register determines the exposure.

CAUTION

1. The de-bounce interval MUST be smaller than the trigger pulse duration. Adjust the interval accordingly.
2. When Triggering is enabled, Internal Exposure timing is not active.

5.5.3 Triggering modes

Exposure Control
When trigger mode is enabled, the exposure time can be set using either the internal exposure timer or the trigger pulse width.

In trigger mode, the camera idles and waits for a trigger signal. Upon receiving the trigger signal, the camera starts integration of the frame, completes the integration, and then reads out the image. If the next trigger is received prior to completion of the readout, the camera will overlap the exposure and readout. You can set the exposure time manually using either the internal exposure register setting or the duration of the trigger pulse. Upon completing the readout, the camera idles awaiting the next trigger pulse.

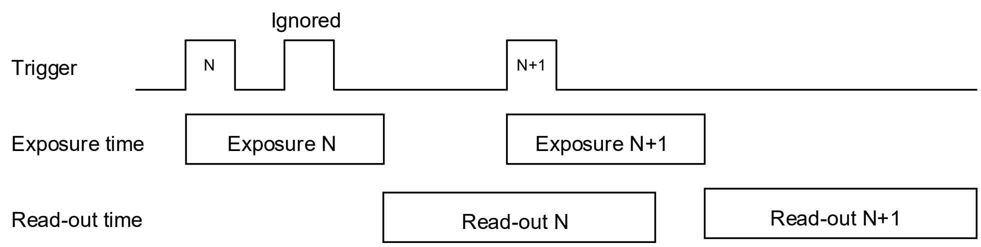


Figure 44: “Fast” Trigger Mode (Internal Exposure Control)

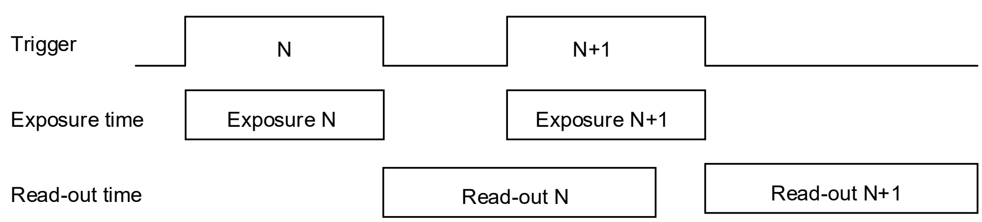


Figure 45: “Fast” Trigger Mode (Pulse Width Exposure Control)

CAUTION ⚠

When using the internal exposure timer, if the next trigger is received prior to the completion of the previous exposure time, the trigger will be ignored.

5.6 Strobes

The camera can provide up to two strobe pulses for synchronization with an external light source, additional cameras, or other peripheral devices. You can set each strobes pulse duration and the delay with respect to the start of the exposure period or the start of the readout period. The maximum pulse duration and the maximum delay can be set up to 1 second with 1.0 µs precision. You can assign the strobe to either external output. The following figure shows two strobe signals positioned with respect to the start of exposure.

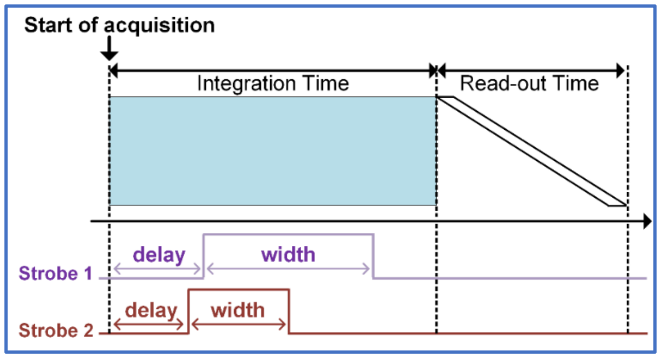


Figure 46: Strobe positioning with respect to exposure start

5.7 Video Amplifier Gain and Offset

5.7.1 Analog Gain

The cameras provide 1x (0dB), 1.2x (1.6 dB), 1.87x (5.43 dB) and 3.17x (10.0 dB) analog gain. Analog gain should always be applied before digital gain.

5.7.2 Digital Gain

Digital gain can be varied from 1x (0 dB) to 15.9x (24 dB) with a precision of ~0.00097x using the raw (fine) gain control. There are 15,360 gain steps from 1x gain to 15.9x gain. Each step increases the gain by 0.000969932x or 1/1031 from 1024 (1.0x gain) to 16384 (15.9x gain). Digital Gain does not provide any improved contrast and should be used cautiously.

To determine the gain step when the gain value is known, use the following steps:

1. Subtract 1.0 from the desired gain multiplier (e.g. 2.54x gain).
2. Multiply the result by 1031.
3. Add 1024.

Or use this formula:

$$\text{Gain coefficient} = [[\text{Desired gain} - 1] *1031] +1024.$$

If the desired gain is in dB, use the following formula:

$$\text{Gain coefficient} = [[[\text{anti-log}_{10}(\text{Desired gain (dB)}/20)]-1]*1031]+1024.$$

EXAMPLES:
1) Desired gain is 7.9x (17.95 dB): [(7.9 – 1.0)*1031]+1024 = 8137.
Set coefficient to 8137.
2) Desired gain is 6 dB, then the code is 2055. Minimum setting is 1024 corresponding to 1x gain.

Below are other examples:

Gain (dB)	Multiplier	Coefficient
0 dB	1x	1024
3 dB	1.41254x	1449
6 dB	1.99526x	2050
12 dB	3.98107x	4097

5.7.3 Digital Offset

Digital offset is a digital count added or subtracted from each pixel. The range is - 512 to +511 counts.

5.7.4 Black Level Auto-calibration and Black Level Offset

The camera automatically adjusts the black level based on measurements of the dark reference lines at the start of each frame. Imperx recommends leaving the black level auto-calibration engaged. If the auto-calibration feature is disabled, you can set the Black Level Offset and adjust it by – 512/+511 counts. Black level will vary with temperature and gain settings.

5.8 Data Output Format

5.8.1 Bit Depth

The image sensor digitization level is fixed at 10-bits, which enables 8-bit or 10-bit data format output. With 8-bit output, the camera uses the standard bit reduction process and truncates the least significant bits.

10-bit digitization

- If the camera is set to output 10-bit data, the sensor data bits map directly to D0 (LSB) to D9 (MSB).
- If the camera is set to output 8-bit data, the sensor data most significant data bits (P2 to P9) map to D0 (LSB) to D7 (MSB).

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	P1	P0

Figure 47: 10-bit internal Digitization with 8 and 10-bit outputs

5.8.2 Output Taps

The Cheetah camera series supports Camera Link Base (2 Tap), Medium (4 tap), Full (8 tap) or Deca (10 taps). The amount of data that can be transferred per unit of time increases with the number of taps selected. The camera reduces the image sensor output rate to match the bandwidth of the output based on the number of taps selected. You can fine-tune the line time to match the frame grabber capture rate by adjusting the pixel clock.

5.9 Pulse Generator

The camera has a built-in pulse generator that you can program to generate a discrete sequence of pulses or a continuous sequence (Figure 48). You can use the pulse generator as a trigger signal or map it to one of the outputs (refer to 5.10.1 Input / Output Mapping). Set the discrete number of pulses 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 x 1000.
- **Width** – Specifies the amount of time (determined by the granularity) that the pulse remains at a high level before falling to a low level. Minimum value is 1, maximum is 524,287.
- **Period** – Indicates the amount of time (also determined by the granularity) between consecutive pulses. Minimum value is 1, maximum is 1,048,575.

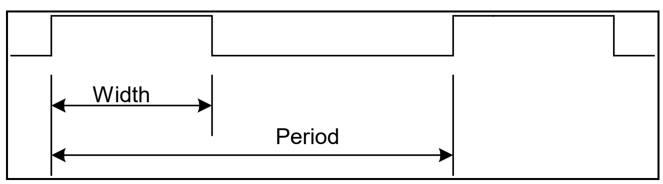


Figure 48: Internal pulse generator

5.10 Input / Output Control

5.10.1 Input / Output Mapping

The camera has two external inputs (1 TTL input and 1 opto-coupled input) and 2 external outputs (1 TTL output and 1 opto-coupled switch) wired to the 12 pin HIROSE connector on the back of the camera. In addition to these inputs and outputs, Camera Link inputs (CC1 and CC2) are also available. You can map CC1 and CC2 or either external input to the Trigger input. You can map the camera outputs to: Trigger, Pulse Generator, Strobe One, or Strobe Two. For each mapped signal, you can select active High or active Low. All possible mapping options for the camera inputs and outputs are shown in the following tables.

Table 22: Cheetah input mapping

Input Signals	**IN1**	**IN2**	**CC1**	**CC2**
Trigger	✓	✓	✓	✓

Table 23: Cheetah output mapping

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

5.11 Test Image Patterns

5.11.1 Test Image patterns

The camera can output several test images to verify the camera's general performance and connectivity to the frame grabber. This ensures that all the major modules in the hardware are working properly and that the connection between the frame grabber and the camera is synchronized, that is, the image framing, output mode, communication rate, and so on are properly configured. Note that the test image patterns do not exercise and verify image sensor functionality. The following test images are available (also see section 4.8.6 Data Output Control):

Table 24: Test patterns

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).

5.12 White Balance and Color Conversion

5.12.1 White Balance Correction

The color representation in the image depends on the spectral content 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 all of the image sensor's red (R), green (G), and blue (B) pixels, analyzes the data, and adjusts the color gain coefficients for each color pixel to properly proportion the colors and make white objects appear white. The algorithm collects data from the entire image and can work in four different modes: AWB Once, AWB Tracking, and Manual.

Table 25: Automatic white balance (AWB) modes

AWB Mode	Description
Off	No white balance correction performed.
Once	Camera analyzes one image frame, calculates only one set of coefficients, and corrects all subsequent frames with this set of coefficients.
Tracking	Camera analyzes every frame, derives a set of correction coefficients for each frame, and applies them to the next frame. You can select five tracking speeds.
Manual	Camera uses the correction coefficients you enter (see TIP below)

To get the best white balance for the R, G, and B coefficients please refer to the TIP in 4.8.7 Color Control section.

5.13 Transfer Function Correction LUT

The user defined LUT (Lookup Table) feature allows you to transform the original video data into any arbitrary value. The LUT is designed to transform any 12-bit value into any other 12-bit value. For the 10-bit Python sensor, the camera multiplies the 10-bit pixel data by 4 to get 12-bit pixel data for input into the 12-bit LUT. After the 12-bit LUT transforms the data, the camera divides the 12-bit data by 4 to get 10-bit pixel values for output to the camera interface (refer to the following figure). The camera supports two separate lookup tables, each consisting of 4096 entries, with each entry being 12-bits wide. Both LUTs are factory programmed with a standard Gamma 0.45 and available for modifications. You can generate and upload your custom LUT using the Cheetah Configuration software.

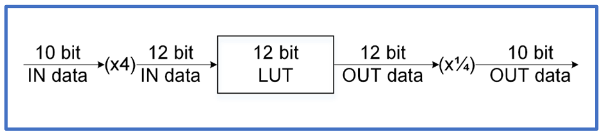


Figure 49: Look up table

5.13.1 Standard Gamma Correction

The image generated by the camera is normally viewed on a monitor and does not have a linear transfer function, that is, the display brightness is not linearly proportional to the scene brightness (as captured by the camera). As the object brightness is lowered, 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, which is called gamma correction. Gamma correction can also help map the camera's wider dynamic range to the limited dynamic range of the display.. If enabled, the video signal is transformed by a non-linear function close to the square root function (0.45 power) as shown in the following formula. In the digital domain, this is a nonlinear conversion from 12-bit to 12-bit.

$$\text{Output signal [V]} = (\text{input signal [V]})^{0.45} \qquad (2.4)$$

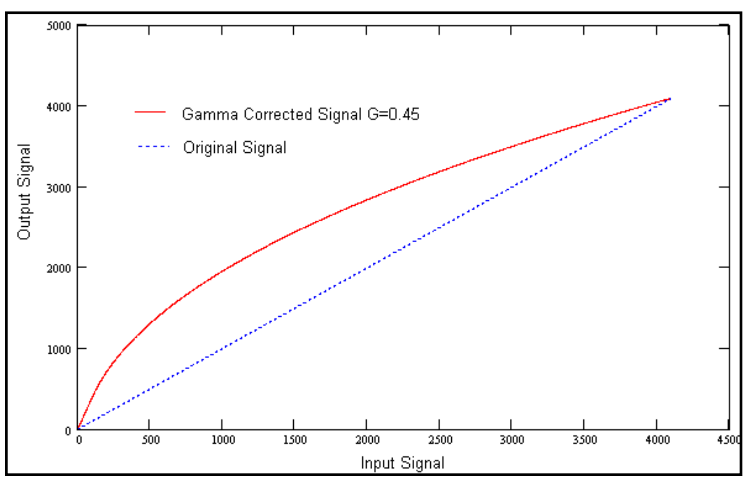


Figure 50: Gamma corrected video signal

5.14 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. However, some pixels deviate from the average pixel sensitivity and are called “defective pixels.” In most cases, defective pixels are responsive to light, and rarely is a pixel totally dark or totally bright. There are two major types of pixel defects: defective and hot.

Defective – these are pixels whose sensitivity deviates due to fluctuations in the CMOS manufacturing process. During final camera testing at the factory up to 1024 defective pixels are identified and will be automatically corrected if defective pixel correction is enabled. Two types of defective pixels are possible:

- **Dark** –a pixel whose sensitivity is lower than the sensitivity of the adjacent pixels. In some cases, this pixel will have no response (completely dark).
- **Bright** – a pixel whose sensitivity is higher than the sensitivity of the adjacent pixels. In some cases, this pixel will have full response (completely bright).

Hot – these are pixels that in normal camera operation behave as normal pixels (the sensitivity is equal to one of the adjacent pixels). But during long exposures or at elevated temperatures, the pixel becomes far brighter than the average of the pixels surrounding it. In some cases, the pixel becomes so bright that it saturates. Final camera testing at the factory identifies and automatically corrects up to 8192 hot pixels.

5.14.1 Static Pixel Correction

Static pixel maps provide one method of correcting defective and hot pixels. During factory testing, engineers identify the coordinates of defective and hot pixels. They create a map file listing the pixel coordinates of these bad pixels by row and column, and the camera corrects the defective and hot pixels found at these coordinates. The map file downloads into the camera's non-volatile memory.

When defective pixel map is enabled, the camera compares each pixel’s coordinates with entries in the DPM. If a match is found, the camera corrects the defective pixel. The same methodology is used to correct hot pixels. You can display the Defective/Hot Pixel Map from the CamConfig main menu.

You can also create and upload your own DPM/HPM to resolve issue unique to your application (see section 9 Creating DPC / HPC Tables).

5.14.2 Dynamic Pixel Correction

Dynamic pixel correction provides another method of correcting defective and hot pixels. Dynamic correction works without preloaded pixel maps. Instead, you set a dynamic threshold value between zero and 4096 (12-bit) counts. The threshold determines how much a pixel’s luminance can deviate from neighboring pixels. If the deviation between bright or dark is too great, the camera corrects the pixel.

Dynamic and Static corrections can be enabled independently or simultaneously.

5.15 Flat Field and FPN Correction

The camera provides a factory installed flat field correction (FFC) algorithm to correct some of the image sensor non-uniformity. It also employs a fixed pattern noise (FPN) algorithm to correct noise within the image sensor. You can upload a user-created FFC table. You can also disable both the FFC and FPN corrections, if desired.

5.16 Camera Interface

5.16.1 Temperature Monitor

The camera has a built-in temperature sensor that monitors the internal camera temperature. The sensor is placed on the hottest spot in the camera. The internal camera temperature is displayed on the Camera Configuration Utility screen and can be queried at any time (refer to 3.3.4.13 Current Camera Temperature section).

5.16.2 Exposure Time Monitor

The camera has a built-in exposure time monitor. In any mode of operation (i.e., normal, AOI, and so on), you can query the camera for the current exposure time by issuing a command (refer to the section 3.3.4.7 Current Exposure Time section). The current camera integration time in units of microseconds will be returned.

5.16.3 Frame Time Monitor

The camera has a built-in frame time monitor. In any mode of operation (i.e., normal, AOI, and so on), you can query the camera for the current frame time by issuing a command (refer to the 3.3.4.3 Current Frame Time section). The current camera frame time in microseconds will be returned.

5.16.4 Current image size

The camera image size can change based on a camera feature selected. In any mode of operation (i.e., normal, AOI, etc.), you can query the camera for the current image size by issuing a command (refer to the 3.3.4.1 Current Horizontal Frame Size and 3.3.4.2 Current Vertical Frame Sizesections). The current camera image size in (pixels x lines) will be returned.

5.16.5 Auto Gain and Auto Exposure Control (AGC/AEC)

Automatic Exposure (and Gain) Control keeps the same image brightness in spite of changing light conditions. You can enable both Automatic Exposure Control (AEC) and Automatic Gain Control (AGC) simultaneously. In either mode, you set the image brightness (luminance) target level in counts, and the camera adjusts the exposure or gain accordingly. The target

luminance can be the average luminance or peak brightness within the entire image (refer to the section3.3.5 AGC/AEC registers) or within a defined Area of Interest (AOI).
If both AEC and AGC are enabled, the camera adjusts the exposure first within the preset minimum/maximum limits you set. If the exposure reaches the maximum limit, the camera indicates the limit has been reached and begins increasing the gain.

The camera displays the current values for AGC/AEC luminance, current exposure, and current gain.

CAUTION

In some rapidly changing bright light conditions, an image brightness oscillation (image intensity flipping from bright to dark) could occur. To prevent this situation, increase the minimum exposure limit or decrease the AEC speed, or use an AOI for the luminance target to control the intensity variability.

6 Image Sensor Technology

6.1 General information

A CMOS camera is an electronic device for converting light into an electrical signal. The C5180, C4181, and C4180 Python cameras contain ON Semiconductor CMOS (Complementary Metal-Oxide Semiconductor) image sensors.

The sensor consists of a two-dimensional array of silicon photodiodes, also known as pixels. The photons falling on the CMOS surface create photoelectrons within the pixels, and 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 intensity and exposure time, the number of electrons varies with the wavelength of the incident light.

In general operation, when the desired exposure time is reached, the photo-electrons collected within each photodiode move onto a storage register within the pixel. The pixels are then read out one row at a time, processed in the analog domain, and digitized to 10 bits. Frame time, or read-out time, is the time interval required for all the pixels from the entire imager to read out of the image sensor. While reading out the image from the storage registers within each pixel, the camera captures the next image overlapping the exposure of the next image with the readout of the current image. The exposure is timed to end just as the readout of the previous frame ends and the readout of the next frame begins.

Unlike traditional CCD image sensors, the CMOS image sensor digitizes each pixel within a row simultaneously. This allows for more settling time, which lowers the overall noise floor and provides improved sensitivity. The low noise floor, combined with a reasonably large pixel charge capacity, translates into a dynamic range of 59 dB.
A set of color filters (red, green, and blue) arranged in a Bayer pattern over the pixels generates color images.

6.1.1 A/D Architecture and Frame Rate Controls

The C5180, C4181, and C4180 image sensors multiplex 80 (C5180) and 64 (C4181 and C4180) columns respectively into an array of 64 A/D converters. The camera takes care of all the details of re-ordering the lines so they are sequentially deposited in computer memory. Unlike a CCD sensor where digitization occurs within one pixel-time, these cameras perform digitization at 1/64th the pixel rate (64 A/D converters), and the digitization has a depth of 10 bits.

The image sensor provides up to 32 Low-Voltage Differential Signaling (LVDS) outputs so the time to read out one line from the image sensor is far less than the time necessary to capture the data using the CXP interface. The camera compensates for this mismatch in data output rate versus data capture rate using two methods: a variable pixel clock for line readout and the ability to add 1 microsecond of delay (row overhead) time at the end of each line output by the camera. Slowing down the pixel line clock and adding delay (dead time) at the end of each line allow the Camera Link frame grabber to keep pace with the camera output

The following figure shows a typical CMOS image sensor architecture.

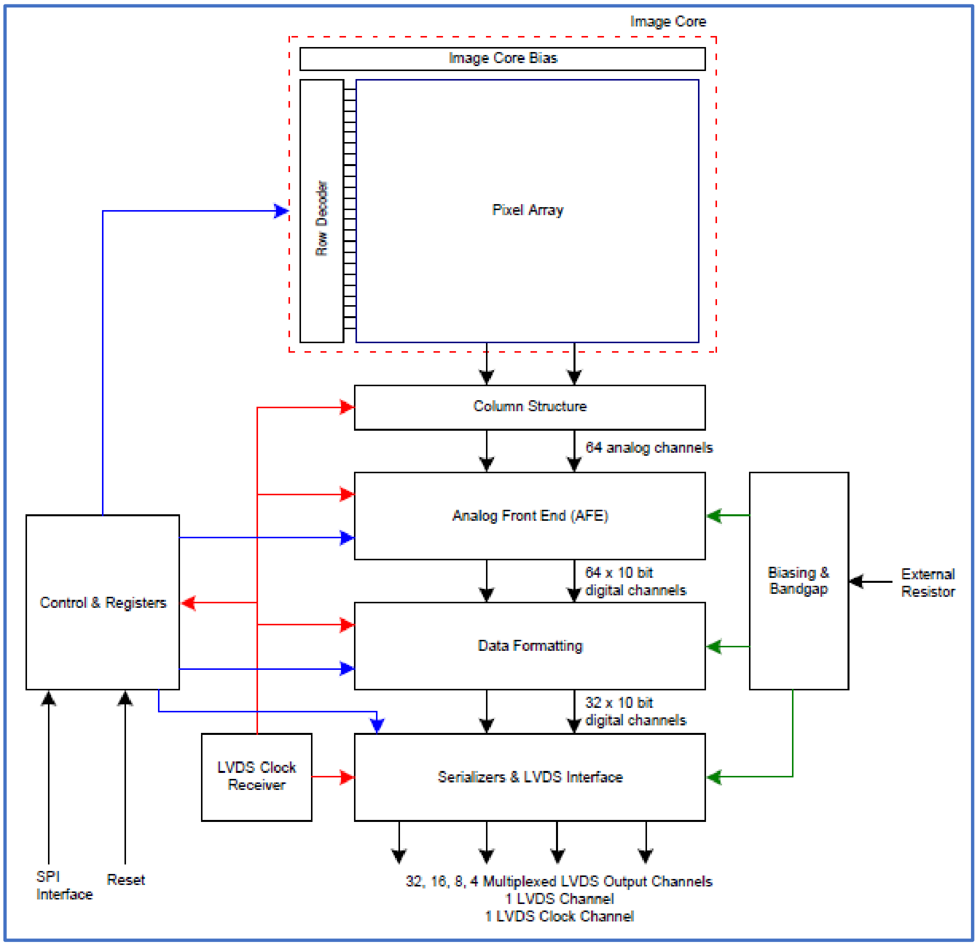


Figure 51: Typical CMOS image sensor architecture

6.1.2 Spectral Sensitivity

The camera's spectral response is shown in the following two figures.

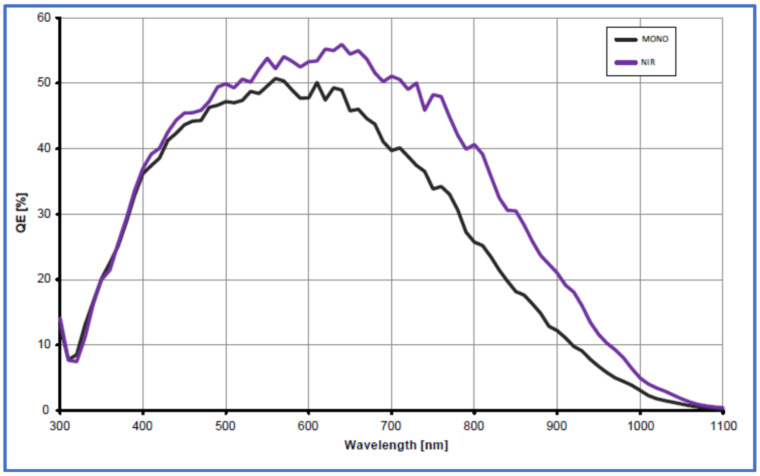


Figure 52: Python CMOS mono spectral response (monochrome, cover glass)

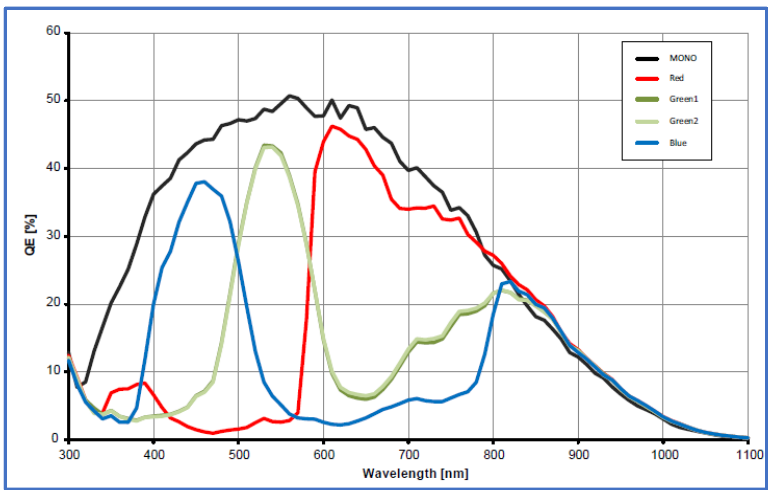


Figure 53: Python CMOS typical color spectral response (micro lens, cover glass)

6.1.3 Bayer Pattern Information

Cheetah Python cameras are available with a Monochrome or Color CMOS imager. Color filters (red, green, and blue) arranged in a Bayer pattern and placed over the pixels generate color images. The starting color is red.

7 Configuration Registers

7.1 Abbreviations

AEC_EXP_MAX, AEC_EXP_MIN – Max. and Min. Exposure Time for AEC
AGC_GN_MAX, AGC_GN_MIN – Max. and Min. Gain Limit for AGC
AOI_VER_OFF, AOI_HRZ_OFF – AOI vertical and horizontal offset
AOI_VER_SZE, AOI_HRZ_SZE – AOI vertical and horizontal size
CAM_ATTRIBUTES – Camera attributes (SROI, AEC, AGC)
CUR_EXP_TIM – Current Exposure time
CUR_FRM_TIM – Current Frame time
GAIN_LUM_STAT – Gain and Luminance status
HRZ_SZE, VER_SZE – Current horizontal and vertical image size
INT_EXP_TIM – Exposure time for the Internal Exposer Mode
MAX_EXP_TIM, **MIN_EXP_TIM** – Max. and Min. Exposure time
MAX_HRZ_SZE, MIN_HRZ_SZE – Max. and Min. horizontal image size – camera dependent
MAX_VER_SZE, MIN_VER_SZE – Max. and Min. vertical image size – camera dependent
MIN_FRM_TIM – Minimum Frame time – camera dependent
PIXEL_CLK – Current Pixel Clock Rate
PIXEL_CLK_MAX – Current Maximum Pixel Clock Rate
RW – read/write, **RO** – read only, **WO** – write only
PAOI_VER_OFF, PAOI_HRZ_OFF – Processing AOI vertical and horizontal offset
PAOI_VER_SZE, PAOI_HRZ_SZE – Processing AOI vertical and horizontal size
TMPR_STAT – Current temperature of a camera

7.2 Saving and Restoring Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x6000	Boot From	RW	0x0 - Factory, 0x1 - User 1, 0x2 - User 2	0x00000000	0x00000002
0x601C	Soft Reset	WO	Command	0xDEDBEEF	0xDEDBEEF
0x6060	Load From Factory	WO	Command	0x00000000	
0x6064	Load From User1	WO	Command	0x00000000	
0x6068	Load From User2	WO	Command	0x00000000	
0x6074	Save to User1	WO	Command	0x00000000	
0x6078	Save to User2	WO	Command	0x00000000	

7.3 Camera Information Registers

Address	Register Name	Type	Value
0x6004	Firmware Revision	RO	d (23:0) – <Firmware Revision> d (27:24) – <Camera Type: 0xB – mono or ENIR, 0xC – color> d (31:28) <Firmware Image>
0x6038	Firmware Build Number	RO	<Firmware Build Number>
0x6008	FPGA & EPCS & Customer ID	RO	<Image_ID & Sensor Type & FWare Rev>
0x600C	Test Register	RW	0x76543210 (Default)
0x608C	Minimum Frame Time	RO	<MIN_FRM_TIM>
0x6010	Current Camera Temperature	RO	<TMPR_STATUS>
0x6020	Current Pixel Clock Rate	RO	<PIXEL_CLK>
0x6080	Current Exposure Time	RO	<CUR_EXP_TIM>
0x6088	Max/Min Exposure Time	RO	d (23:0) – <MAX_EXP_TIM> d (31:24) – <MIN_EXP_TIM>
0x60AC	Camera Attributes	RO	d (29) – <PAOI: 0x0 – not available, 0x1 – available> d (30) – <AEC: 0x0 – not available, 0x1 – available> d (31) – <AGC: 0x0 – not available, 0x1 – available>
0x60B8	Current Gain & Luminance	RO	d (13:0) – <Current Gain > d (27:16) – <Current Average Luminance> d (28) – <Gain Minimum Limit: 0x1 – reached 0x0 – not reached> d (29) – <Gain Maximum Limit: 0x1 – reached 0x0 – not reached> d (30) – <Exposure Minimum Limit: 0x1 – reached 0x0 – not reached> d (31) – <Exposure Maximum Limit: 0x1 – reached 0x0 – not reached >
0x6084	Current Frame Time	RO	<CUR_FRM_TIM>
0x6090	Current Horizontal Frame Size	RO	<HRZ_SZE>
0x6094	Current Vertical Frame Size	RO	<VER_SZE>
0x60A4	Horizontal Size (Max)	RO	<MAX_HRZ_SZE>
0x60A8	Vertical Size (Max)	RO	<MAX_VER_SZE>
0x60B0	Current Pixel Clock Max	RO	<PIXEL_CLK_MAX>
0x603C	Camera ID Type	RO	0x2 – Cheetah Python

7.4 AEC/AGC/AWB Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0500	Auto Exposure Control	RW	0x0 – disable 0x1 – enable	0x00000000	0x00000001
0x0514	AEC Maximum Exposure Time Limit	RW	<AEC_EXP_MAX>	<AEC_EXP_MIN> + 1	<MAX_EXP_TIM>
0x0510	AEC Minimum Exposure Time	RW	<AEC_EXP_MIN>	0x00000004	<AEC_EXP_MAX> - 1

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0504	Auto Gain Control	RW	0x0 – disable 0x1 – enable	0x00000000	0x00000001
0x051C	Maximum Gain Limit	RW	<AGC_GN_Max>	<AGC_GN_Min> + 1	0x00003FFF
0x0518	Minimum Gain Limit	RW	<AGC_GN_Min>	0x00000400	<AGC_GN_Max> - 1
0x050C	Luminance Level Threshold	RW	<LumLevel>	0x00000001	0x00000FFF
0x0508	Luminance Type Selection	RW	0x0 – average 0x1 – peak 0x2 – reserved 0x3 – reserved	0x00000000	0x00000003
0x0520	Exposure/Gain Correction Speed	RW	0x0 – 1x, 0x1 – 2x, 0x2 – 3x, 0x3 – 4x	0x00000000	0x00000003

7.5 Acquisition Registers (stored in Flash)

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0000	AOI Vertical Offset (Y1)	RW	<AOI_VER_OFF> d (11:0) multiple of 2	0x00000000	<MAX_VER_SZE>-2
0x0004	AOI Vertical Size (H1)	RW	<AOI_VER_SZE> Height Value d (11:0) multiple of 2	0x00000002	<MAX_VER_SZE>
0x0020	PAOI Enable	RW	0x0 – PAOI disable 0x1 – PAOI include 0x2 – PAOI exclude 0x3 – PAOI for AEC/AGC include 0x4 – PAOI for AEC/AGC exclude 0x5 – PAOI for AWB include 0x6 – PAOI for AWB exclude 0x7 – PAOI for LUT include 0x8 – PAOI for LUT exclude	0x00000000	0x00000008
0x0018	PAOI Horizontal Offset	RW	<PAOI_HRZ_OFF> Uses a multiple of 8	0x00000000	<MAX_HRZ_SZE> - <PAOI_HRZ_SZE>-8
0x001C	PAOI Horizontal Size	RW	<PAOI_HRZ_SZE> Uses a multiple of 8	<PAOI_HRZ_OFF>+8	<MAX_HRZ_SZE>
0x0010	PAOI Vertical Offset	RW	<PAOI_VER_OFF> Uses a multiple of 2	0x00000000	<MAX_VER_SZE> - <PAOI_VER_SZE>-2
0x0014	PAOI Vertical Size	RW	<PAOI_VER_SZE> Uses a multiple of 2	<PAOI_VER_OFF>+2	<MAX_VER_SZE>
0x0008	AOI Horizontal Offset (X1)	RW	<AOI_HRZ_OFF> Offset Value d(11:0) multiple of 8	0x00000000	<MAX_HRZ_SZE>-8

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x000C	AOI Horizontal Size (W1)	RW	<AOI_HRZ_SZE> Width Value d(11:0) multiple of 8	0x00000008	<MAX_HRZ_SZE>
0x0700	Fixed Frame Period Enable	RW	0x0 – disable, 0x1 – enable	0x00000000	0x00000001
0x0704	Fixed Frame Period (in microseconds)	RW	<Frame Time>	<MIN_FRM_TIM>	0x000F4240
0x0404	Pixel Clock Rate (in megahertz)	RW	<Pixel Clock Rate in MHz>	0x00000020	<PIXEL_CLK_MAX>
0x0708	Zero-ROT Enable	RW	0x0 – disable, 0x1 – enable	0x00000000	0x00000001
0x0720	Exposure Control mode	RW	0x0 – off, 0x1 – trigger pulse width 0x2 – internal time 0x3 – reserved	0x00000000	0x00000003
0x0728	Exposure Time (Internal)	RW	<INT_EXP_TIM>	0x00000000	0x000F4240
0x073C	Subsampling Mode	RW	0x0 – off, 0x1 – subsample x 0x2 – subsample y 0x3 – subsample x & y	0x00000000	0x00000003
0x0754	Averaging Mode	RW	0x0 – off, 0x1 – average x 0x2 – average y 0x3 – average x & y	0x00000000	0x00000003
0x0748	Analog Gain	RW	0x0 – 1.0x 0x1 – 1.26x 0x2 – 1.87x 0x3 – 3.17x	0x00000000	0x0000003
0x0438	Digital Gain	RW	<Digital Gain Value> (1024 to 16383)	0x00000400	0x00003FFF
0x043C	Digital Offset	RW	<Dig. Offset Value> (signed -512 to +511)	0x00000000	0x000003FF
0x0758	Black Level Auto-Cal	RW	0x0 – disable 0x1 – enable	0x00000000	0x00000001
0x075C	Black Level Offset	RW	<Black Level Offset> (signed - 512 to +511)	0x00000000	0x000001FF

7.6 Trigger Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0650	Trigger Input Selector	RW	0x0 – IN1, 0x4 – Internal, 0x1 – IN2, 0x5 - Software 0x2 – CC1, 0x3 – CC2,	0x00000000	0x00000005
0x0658	Triggering Edge Selector	RW	0x0 – Rising, 0x1 – Falling	0x00000000	0x00000001
0x0654	Trigger Enable	RW	0x0 – enable, 0x1 – disable	0x00000000	0x00000001

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x065C	De-bounce Time Selector	RW	0x0 – no de-bounce, 0x4 – 10 µs, 0x5 – 50µs, 0x1 – 100µs, 0x6 – 500 µs, 0x2 – 1ms, 0x7 – 5ms, 0x3 – 10ms	0x00000000	0x00000007
0x6030	Software Trigger Start (Single Pulse Generator)	WO	Command	0x00000000	
0x0660	Trigger Exposure Delay	RW	<TRG_EXP_DEL>	0x00000000	0x000F4240
0x0664	Ignore Next Trigger	RW	0x0 – accept next trigger 0x1 – ignore next trigger	0x00000000	0x00000001

7.7 Pulse Generator Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0690	Pulse Gen. Granularity	RW	0x0 – 1x, 0x2 – 100x, 0x1 – 10x, 0x3 – 1000x	0x00000000	0x00000003
0x0694	Pulse Gen. Pulse Width	RW	<Pulse Width>	0x00000001	0x0007FFFF
0x0698	Pulse Gen. Pulse Period	RO	<Pulse Period>	0x00000001	0x000FFFFF
0x069C	Pulse Gen. # of Pulses	RW	<Number of Pulses>	0x00000001	0x0000FFFF
0x06A0	Pulse Gen. Enable	RW	0x0 – Disable, 0x1 – Enable	0x00000000	0x00000001
0x06A4	Pulse Gen. Mode	RW	0x0 – Continuous Mode 0x1 – Burst Mode	0x00000000	0x00000001

7.8 Test Pattern Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0428	Test Mode Selector	RW	0x0 – Disable 0x1 – H Ramp Static 0x2 – V Ramp Static 0x3 – H Ramp Moving 0x4 – V Ramp Moving 0x5 – Cross-Hair	0x00000000	0x00000005

7.9 Strobe Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0630	Strobe 1 Enable	RW	0x0 – Disable, 0x1 – Enable	0x00000000	0x00000001
0x0634	Strobe 1 Start Reference	RW	0x0 – Exposure Start 0x1 – Readout Start	0x00000000	0x00000001
0x0638	Strobe 1 Delay	RW	< S1 Delay Value> (in µs)	0x00000000	0x000F4240
0x063C	Strobe 1 Duration	RW	<S1 Duration Value> (in µs)	0x00000000	0x000F4240
0x0640	Strobe 2 Enable	RW	0x0 – Disable, 0x1 – Enable	0x00000000	0x00000001
0x0644	Strobe 2 Start Reference	RW	0x0 – Exposure Start 0x1 – Readout Start	0x00000000	0x00000001
0x0648	Strobe 2 Delay	RW	<S2 Delay Value> (in µs)	0x00000000	0x000F4240
0x064C	Strobe 2 Duration	RW	<S2 Duration Value> (in µs)	0x00000000	0x000F4240

7.10 Input / Output Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0680	OUT1 Polarity Selector	RW	0x0 -Active L, 0x1 - Active H	0x00000000	0x00000001
0x0684	OUT1 Output Selector	RW	0x0 – no mapping 0x1 – trigger pulse 0x2 – pulse generator 0x3 – Strobe 1 0x4 – Strobe 2	0x00000000	0x00000004
0x0688	OUT2 Polarity Selector	RW	0x0 -Active L, 0x1 - Active H	0x00000000	0x00000001
0x068C	OUT2 Output Selector	RW	0x0 – no mapping 0x1 – trigger pulse 0x2 – pulse generator 0x3 – Strobe 1 0x4 – Strobe 2	0x00000000	0x00000004

7.11 Output Data Format Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x040C	Bit Depth Selector	RW	0x0 – 8-bit, 0x1 -10-bit	0x00000000	0x00000001
0x0424	Camera Link Output Selector	RW	0x0 – N/A 0x1 – Dual 0x2 – 4 Taps, 0x3 – 8 Taps, 0x4 – 10 Taps	0x00000000	0x00000004

7.12 WB and Color Correction Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0538	White Balance Mode Selector	RW	0x0 - Off, 0x1 - Once, 0x2 – Auto Tracking, 0x3 – Manual	0x00000000	0x00000003
0x053C	AWB tracking speed	RW	0x0 – 1x slowest 0x1 – 2x 0x2 – 3x 0x3 – 4x 0x4 – 5x fastest	0x00000000	0x00000004
0x0540	WB Coef. Red	RW	<WBC_RED>	0x00000000	0x00000FFF
0x0544	WB Coef. Green	RW	<WBC_Green>	0x00000000	0x00000FFF
0x0548	WB Coef. Blue	RW	<WBC_Blue>	0x00000000	0x00000FFF

7.13 Data Correction Registers

Address	Register Name	Type	Usage	MIN Value	MAX Value
0x0410	Look-Up-Table selector	RW	0x0 – LUT 1 0x1 – LUT 2	0x00000000	0x00000001
0x0414	Look-Up-Table	RW	0x0 - Disable 0x1 - Enable	0x00000000	0x00000001
0x0418	Defective Pixel Correction	RW	0x0 – Disable 0x1 – Static, 0x2 – Dynamic 0x3 – Static & Dynamic	0x00000000	0x00000003
0x041C	Hot Pixel Correction	RW	0x0 – Disable 0x1 – Static, 0x2 – Dynamic, 0x3 – Static & Dynamic	0x00000000	0x00000003
0x042C	Dynamic DPC Threshold	RW	<DYN_DPC_TRD>	0x00000000	0x00000FFF
0x0430	Dynamic HPC Threshold	RW	<DYN_HPC_TRD>	0x00000000	0x00000FFF
0x0420	Flat Field Correction	RW	0x0 – Disable 0x1 – Enable	0x00000000	0x00000001
0x0434	Flat Field Selection	RW	0x0 – FFC Factory 0x1 – FFC User	0x00000000	0x00000001
0x0440	FPN Correction	RW	0x0 - Disable 0x1 - Enable	0x00000000	0x00000001

7.14 Manufacturing Data Registers

Address	Register Name	Type	Value
0x7004	Assembly Part Number	RO	<Assembly Part Number_1>
0x7008	Assembly Part Number	RO	<Assembly Part Number_2>
0x700C	Assembly Part Number	RO	<Assembly Part Number_3>
0x7010	Assembly Part Number	RO	<Assembly Part Number_4>
0x7014	Camera Serial Number	RO	<Camera Serial Number_1>
0x7018	Camera Serial Number	RO	<Camera Serial Number_2>
0x701C	CMOS Serial Number	RO	<CMOS Serial Number_1>
0x7020	CMOS Serial Number	RO	<CMOS Serial Number_2>
0x7024	Date of Manufacture	RO	<Date of Manufacture_1>
0x7028	Date of Manufacture	RO	<Date of Manufacture_2>
0x702C	Camera Type	RO	<Type of Camera_1>
0x7030	Camera Type	RO	<Type of Camera_2>
0x7034	Camera Type	RO	<Type of Camera_3>
0x7038	Camera Type	RO	<Type of camera_4>

8 Creating Look-up Tables

8.1 Overview

A Lookup Table (LUT) file can be created using any standard ASCII text editor or by using Microsoft Excel. Additionally, any spreadsheet or mathematical program capable of generating a comma delimited (.csv) file can be used.

8.2 Using an ASCII Text Editor

A custom LUT can be prepared using any ASCII text editor, such as “Notepad” or similar. Alternatively, any spreadsheet program (i.e. Microsoft Excel) can be used by converting the spreadsheet into a comma delimited (.csv) file. In either case, the file must be renamed to include the .lut file extension.

The .lut file has two main sections: a header and a table. The header section is a free text area of up to 256 ASCII characters. Each line of the header section must be terminated in a comma. The table section of the file contains an array of 4096 lines with each line containing an input value followed by a comma and an output value. The input values represent incoming pixels and the output values represent what each incoming pixel should be converted into as an output pixel.

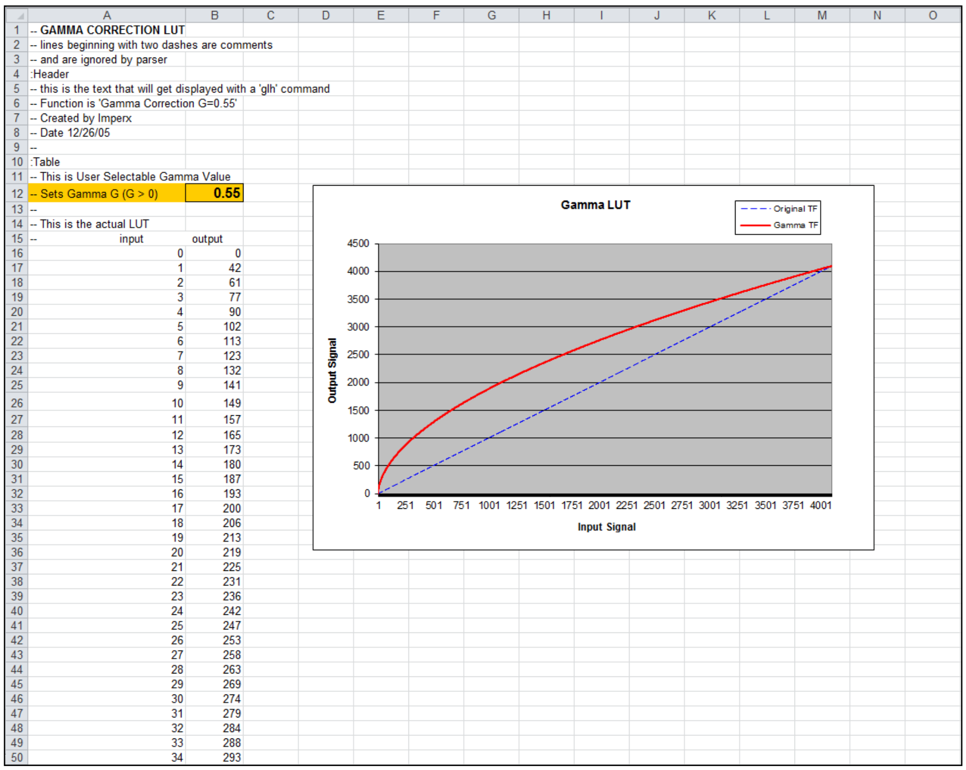
The format of the .LUT file is as follows:

```
-- 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
```

8.3 Using Microsoft Excel

The LUT file can be created in Excel as follows:

1. Create the spreadsheet as shown below (note that 4096 rows are required in the table).
2. Add the necessary equations into the output cells to generate the transfer function required.
3. Save the file as a .csv (comma delimited format).
4. Rename the .csv file to an extension of .lut.



	A	B
1	-- GAMMA CORRECTION LUT	
2	-- lines beginning with two dashes are comments	
3	-- and are ignored by parser	
4	:Header	
5	-- this is the text that will get displayed with a 'glh' command	
6	-- Function is 'Gamma Correction G=0.55'	
7	-- Created by Imperx	
8	-- Date 12/26/05	
9	--	
10	:Table	
11	-- This is User Selectable Gamma Value	
12	-- Sets Gamma G (G > 0)	0.55
13	--	
14	-- This is the actual LUT	
15	-- input	output
16	0	0
17	1	42
18	2	61
19	3	77
20	4	90
21	5	102
22	6	113
23	7	123
24	8	132
25	9	141
26	10	149
27	11	157
28	12	165
29	13	173
30	14	180
31	15	187
32	16	193
33	17	200
34	18	206
35	19	213
36	20	219
37	21	225
38	22	231
39	23	236
40	24	242
41	25	247
42	26	253
43	27	258
44	28	263
45	29	269
46	30	274
47	31	279
48	32	284
49	33	288
50	34	293

Figure 54: Sample spreadsheet

9 Creating DPC / HPC Tables

9.1 Overview

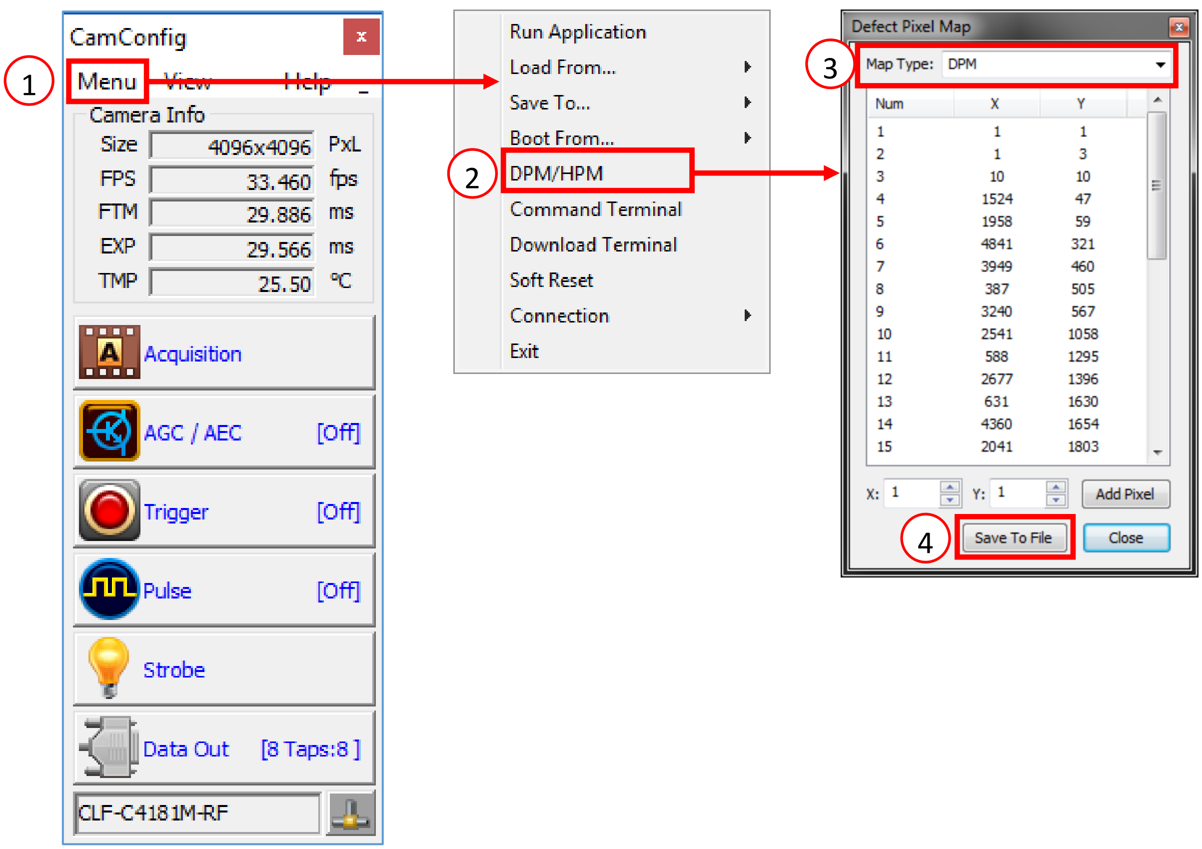
Defective Pixel Correction and Hot Pixel Correction work with predetermined and preloaded Defective and Hot pixel maps. The Defective Pixel Map (DPM) and Hot Pixel Map (HPM) are downloaded into the camera's non-volatile memory.

You can edit the original DPM / HPM file, create your own file and upload it to fit the unique requirements of your operating environment or camera use.

9.2 Accessing DMP / HPM Files

To get the original file from the camera for editing follow steps below:

1) Open the camera's software GUI.
2) Click **Menu** and select **DPM/HPM**. The **Defect Pixel Map** window appears.



3) Select **DPM** or **HPM** in the drop-down menu **Map Type**.
4) Click **Save to File**. Navigate to where you want to save the file and create a file name and extension based on the type of file:
   – Use the extension .dpm if saving a Defective Pixel Map.
   – Use the extension .hpm if saving a Hot Pixel Map.

9.3 Editing DPM / HPM Files

You can edit DPM and HPM files in Microsoft Notepad or any other editing software. The files look like this:

```
-- Defective Pixel Map,
-- Date: 2.23.2018,
-- Model#: CLF-C5180M-RF,
-- Serial#: LAC001,
:Table,
-- Column(X),Row(Y)
        5683,155
        3091,332
        3532,893
         650,1017
         701,1017
        1712,1053
         914,1067
```

Pixel maps have two main sections: a header and a table. The header section is a free text area of up to 256 ASCII characters. Each line of the header section must be terminated with a comma. The table section of the file contains an array of lines with each line containing an X (column number) value followed by a comma and a Y (row number) value.

All pixels are listed in the DPM or HPM in order of increasing Y (row) location. If the Y location is identical, the listing is in order of increasing X (column) location.

The maximum number of pixels in the DMP list is 512 and in HPM list is 4096.
To edit original DPM or HPM file, you need to identify defective or hot pixels, locate and adjust their coordinates, and accurately place pixels' coordinates into the pixel map.

9.3.1 Finding defective pixels

To find all of the defective pixels you need to add to the map, it is recommended that you take an image with a uniform light source illuminating the sensor at about 50% ADU capacity (~2000 for 12-bit, ~500 for 10-bit, ~130 for 8-bit modes).

Ensure that the **DPC** and **HPC** are set to "Static" on the **Data Output** screen of the **CamConfig** GUI, so the camera will correct the known pixel defects. You can then identify any visible pixel defects and add them to the defective pixel maps.

9.3.2 Finding hot pixels

To find all hot pixels that need to be added to the map, put the lens cap on the camera and capture an image after the camera has reached the normal operating temperature. Use the longest expected exposure time at the normal frame rate. If the camera will operate with variable frame rates, set the camera to the slowest frame rate expected.

Ensure that the **HPC** is set to "Static" on the **Data Output** screen of the **CamConfig** GUI, so the camera will correct the known hot pixels automatically. From this image, you can then identify all of the hot pixels not in the factory map and add them to the hot pixel map.

9.3.3 Locating and adding pixel coordinates

Follow the steps below to find first pixel coordinates, locate and adjust defective pixel coordinates, and accurately place defective pixel coordinates into the pixel map.

STEP 1: Find the First Pixel Coordinates

Your frame grabber's first pixel coordinates can affect the location accuracy of defective pixel coordinates. So, you must find the image sensor's first pixel coordinates and potentially adjust the defective pixel coordinates based on your findings.

Click the first pixel at the upper most left corner of the screen to find your frame grabber's first pixel X, Y coordinates (Figure 55). The coordinates will be either 0, 0 or 1, 1:

- If your frame grabber's first pixel coordinates are 0,0, you must add 1 to both the X and Y coordinates of the bad pixel.
- If the first pixel coordinates are 1, 1, do not add 1 to either coordinate.

STEP 2: Find Defective Pixel Coordinates

Click the defective pixel to find its X, Y coordinates (Figure 56).
The Figure 56 shows a pixel defect at location 593, 4816 — where X (Column) = 593 and Y (Row) = 4816.

IMPORTANT: Frame grabbers from different manufacturers may display pixel location coordinates in different order, for example:

X (Column), Y (Row) or,
X (Row), Y (Column).

You must put defective pixel coordinates into the pixel correction map file in this order:
X (Column), Y (Row).

If your frame grabber identifies pixel coordinates by X **(Row)**, Y **(Column)**, you <u>must</u> transpose the coordinates to X (**Column**), Y (**Row**) before entering them into the pixel map files. For example, if the 593, 4816 coordinates in the screen below (Figure 56) had been displayed in this order, where X:593 is row and Y:4816 is column, you would have had to transpose the coordinates to 4816, 593.

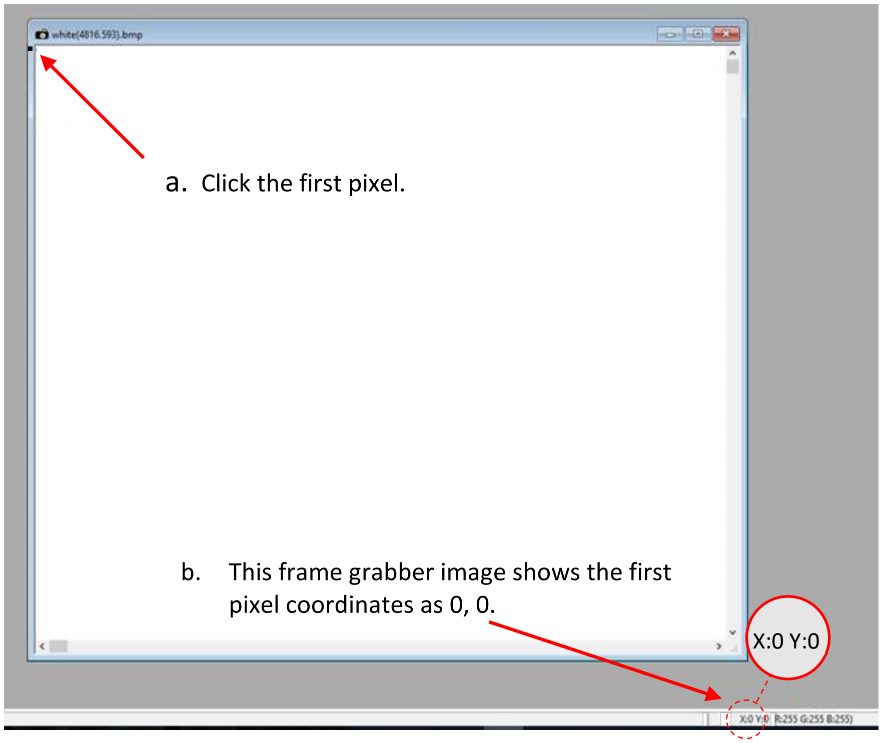


Figure 55: Frame grabber's firs pixel

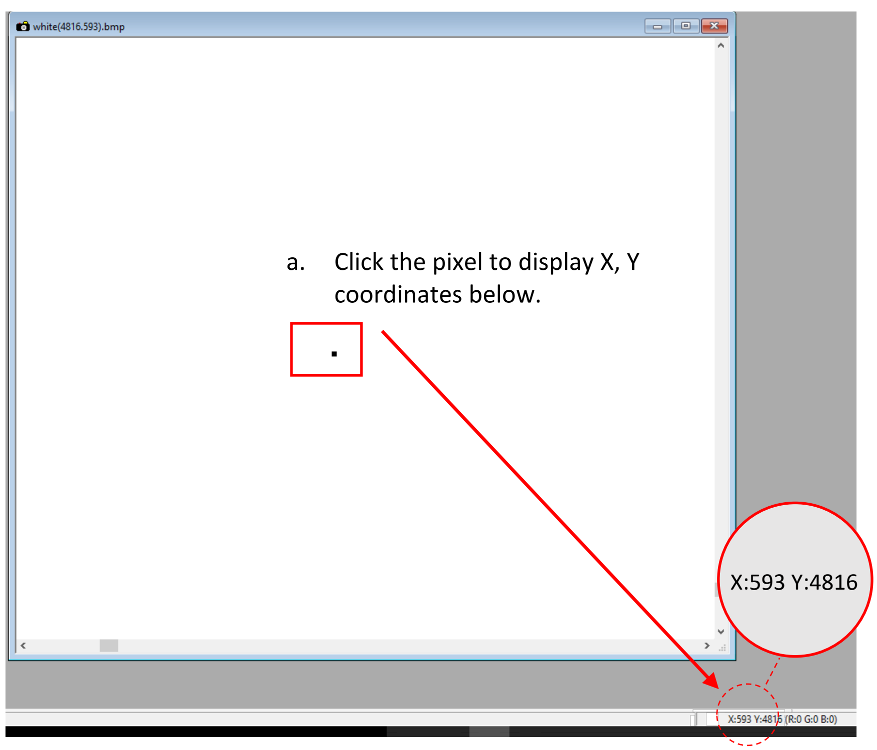


Figure 56: Locating defective pixel

STEP 3: Adjust Defective Pixel Coordinates

As described in **STEP 1**, if the first pixel coordinates are 0, 0, you must adjust the defective pixel coordinates by adding 1 to both coordinates as shown in the following:

593 (+1), 4816 (+1) = 594, 4817

- If the frame grabber pixel coordinates are Column (X), Row (Y), then go to **STEP 4**.
- If the frame grabber pixel coordinates are Row (X), Column (Y), then transpose the coordinates to the form Column, Row and then go to **STEP 4**.

STEP 4: Add Defective Pixel Coordinates to Defective Pixel Map

Place the defective pixel coordinates in the Defective Pixel Map file in ascending (increasing) numerical order of the Y (row) coordinate. The value of all Y coordinates should progressively increase as you look down the list of X, Y coordinates.

Example 1: Different Y coordinates

```
-- Defective Pixel Map,
-- Date: 4.12.2018,
-- Model#: CLF-C5180M-RF,
-- Serial#: LAC001,
:Table,
-- Column(X),Row(Y)
701,1017
100,1018
4325,1019
2241,1020
458,1021
1712,1053
914,1067
3954,1546
2516,1670
3451,3331
1111,4149
95,4364
594,4817
433,4828
205,4899
```

Row coordinates are in ascending order (increasing Y values).

Example 2: Identical Y coordinates

```
-- Defective Pixel Map,
-- Date: 4.12.2018,
-- Model#: CLF-C5180M-RF,
-- Serial#: LAC001,
:Table,
-- Column(X),Row(Y)
650,1017
698,1017
701,1017
100,1018
4325,1019
2241,1020
458,1021
1712,1053
914,1067
3954,1546
2516,1670
3451,3331
1111,4149
95,4364
433,4828
205,4899
```

Column coordinates are in ascending order (increasing X values).

As shown in the **Example 1** above, the Y coordinate of 594, 4817 is higher than **4364** and lower than **4828**. Do not add defective pixel coordinates at the end of the list unless the Y coordinate is the highest of all Y values.

NOTE

If adding a defective pixel with a Y location identical to one or more other defective pixels, insert its coordinates based on the order of increasing X location.

As shown in the **Example 2** above, the Y coordinate of 698, 1017 is identical to two other defective pixels. Place its coordinates between **650,** 1017 and **701,** 1017 because its X location (698) is higher than 650 but lower than 701.

STEP 5: Save your DPM/HPM

- Save your Defective Pixel Map with the file extension .dpm.
- Save your Hot Pixel Map with file extension .hpm

9.4 Creating new DPM / HPM Files

You can create your own DPM and HPM files using any ASCII text editor, such as "Notepad" or similar. Alternatively, any spreadsheet program (i.e. Microsoft Excel) can be used by converting the spreadsheet into a comma delimited (.csv) file. In either case, the file must be renamed to include the .dpm or .hpm file extension. The files look like this:

```
-- Defective Pixel Map,
-- Date: 2.23.2018,
-- Model#: CLF-C5180M-RF,
-- Serial#: LAC001,
:Table,
-- Column(X),Row(Y)
        5683,155
        3091,332
        3532,893
         650,1017
         701,1017
        1712,1053
         914,1067
```

Pixel maps have two main sections: a header and a table. The <u>header section</u> is a free text area of up to 256 ASCII characters. Each line of the header section must be terminated with a comma. The <u>table section</u> of the file contains an array of lines with each line containing an X (column number) value followed by a comma and a Y (row number) value.

All pixels are listed in the DPM or HPM in order of <u>increasing Y (row) location</u>. If the Y location is identical, the listing is in order of increasing X (column) location.

The maximum number of pixels in the DMP list is 512 and in HPM list is 4096.

To create a DPM or HPM file:

1. Identify defective or hot pixels (refer to the sections 9.3.1 Finding defective pixels and 9.3.2 Finding hot pixels).

IMPORTANT: When creating a new pixel map, you need to get all defective pixel visible. Ensure that the **DPC** and **HPC** are set to "Off" on the Data Output screen of the CamConfig GUI, so the camera will not correct the known pixel defects.

2. Locate and adjust defective pixels' coordinates (refer to the section 9.3.3 Locating and adding pixel coordinates, **STEP1 – STEP3**).

3. Place pixels' coordinates into the pixel map and save the file (refer to the section 9.3.3 Locating and adding pixel coordinates **STEP4, STEP5**).

9.5 Uploading DPM / HPM Files

After saving the maps, you can upload them to the camera using the Imperx **Upload Utility**. The Upload Utility ships with your camera and enables uploads of DPM, HPM, and other files to your camera.

To upload DPM and HPM files:

1. Connect and power up your camera.
2. Start the Imperx **Upload Utility** and wait for the Utility to detect the camera (Figure 57).

If the utility does not detect the camera, click **Refresh** to restart the device collection.

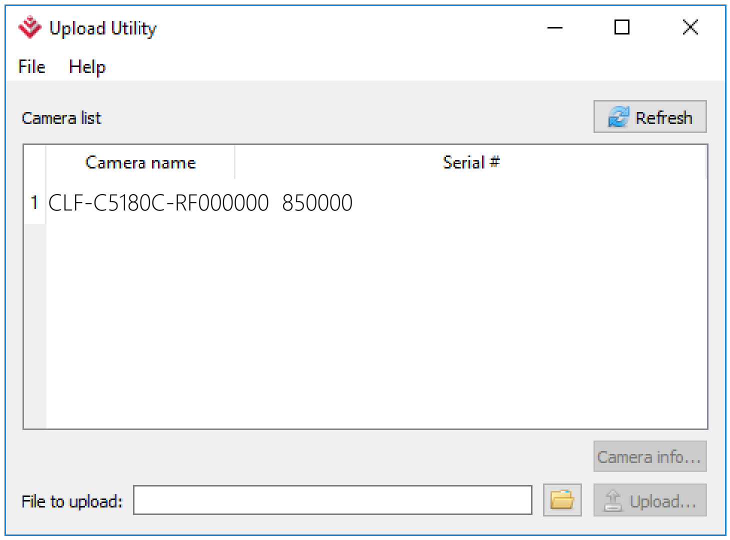


Figure 57: Detect a camera

3. Select the camera to update if more than one appears.

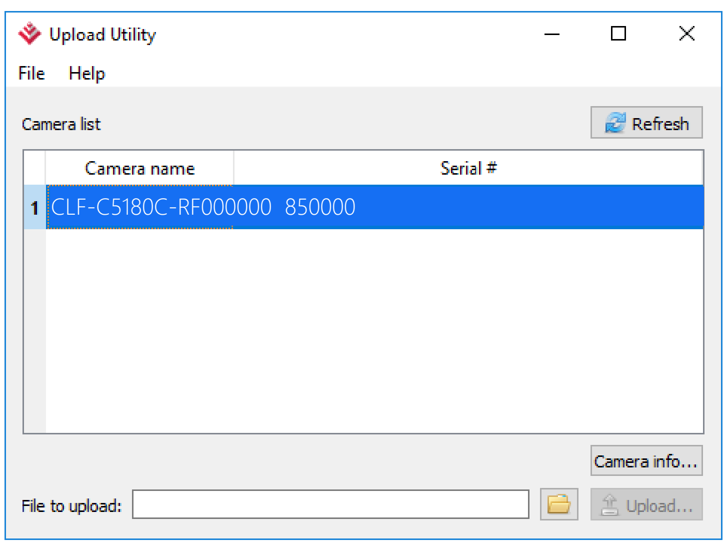


Figure 58: Select detected camera

4. Browse for either the edited .dpm file or .hpm file, select it, and click the **Upload** button. Wait for the upload to finish.

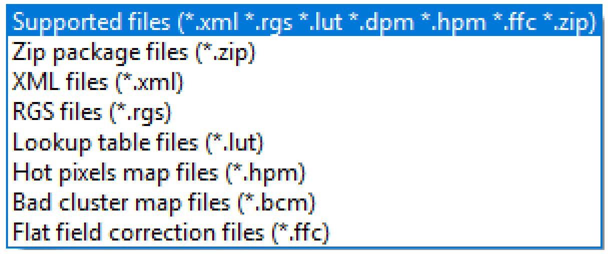


Figure 59: Supported upload files

5. After the upload is completed, do a power cycle on the camera.
6. After the camera re-starts, start the **CamConfig** and select **Data Output**.
7. Ensure that DPC and HPC are set to **Static** so that the camera uses the maps you loaded.
8. Retake images as described in sections 9.3.1 Finding defective pixels and 9.3.2 Finding hot pixels to ensure all defective and hot pixels are now corrected.

Alternatively, you can use **Download Terminal** from the main Menu (see section 4.5 Main GUI Menu).