TELEDYNE PHOTOMETRICS
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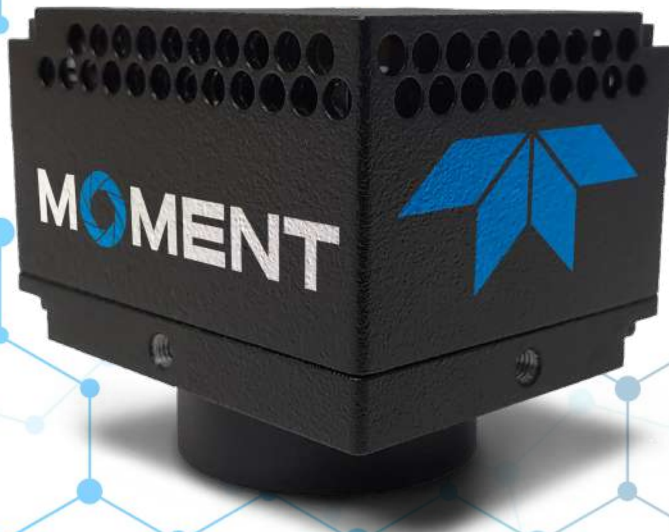

MOMENT

Moment- User Manual

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Teledyne Photometrics warrants this product against substantial defects in materials and/or workmanship for a period of up to two (2) years after shipment. During this period, Teledyne Photometrics will repair the product or, at its sole option, repair or replace any defective part without charge to you. You must deliver the entire product to the Teledyne Photometrics factory or, at our option, to a factory-authorized service center. You are responsible for the shipping costs to return the product. International customers should contact their local Teledyne Photometrics-authorized representative/distributor for repair information and assistance, or visit our technical support page at www.photometrics.com.

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Normal Wear Item Disclaimer

Teledyne Photometrics does not warrant certain items against defect due to normal wear and tear. These items include internal and external shutters, cables, and connectors. *These items carry no warranty, expressed or implied.*

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Owner’s Manual and Troubleshooting

You should read the owner’s manual thoroughly before operating this product. In the unlikely event that you should encounter difficulty operating this product, refer to the owner’s manual. If the problem persists, please contact the Teledyne Photometrics technical support staff or an authorized service representative.

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You must retain your bill of sale (invoice) and present it upon request for service and repairs or provide other proof of purchase satisfactory to Teledyne Photometrics.

You must notify the Teledyne Photometrics factory service center within thirty (30) days after you have taken delivery of a product or part that you believe to be defective. With the exception of customers who claim a “technical issue” with the operation of the product or part, all invoices must be paid in full in accordance with the terms of sale. Failure to pay invoices when due may result in the interruption and/or cancellation of your two (2) year limited warranty and/or any other warranty, expressed or implied.

All warranty service must be made by the Teledyne Photometrics factory or, at our option, an authorized service center.

Before products or parts can be returned for service you must contact the Teledyne Photometrics factory and receive a return authorization number (RMA). Products or parts returned for service without a return authorization evidenced by an RMA will be sent back freight collect.

These warranties are effective only if purchased from the Teledyne Photometrics factory or one of our authorized manufacturer’s representatives or distributors.

Unless specified in the original purchase agreement, Teledyne Photometrics is not responsible for installation, setup, or disassembly at the customer’s location.

Warranties extend only to defects in materials or workmanship as limited above and do not extend to any product or part which has:

- been lost or discarded by you;
- been damaged as a result of misuse, improper installation, faulty or inadequate maintenance, or failure to follow instructions furnished by us;
- had serial numbers removed, altered, defaced, or rendered illegible;
- been subjected to improper or unauthorized repair; or
- been damaged due to fire, flood, radiation, or other “acts of God” or other contingencies beyond the control of Teledyne Photometrics.

After the warranty period has expired, you may contact the Teledyne Photometrics factory or a Teledyne Photometrics-authorized representative for repair information and/or extended warranty plans.

Physically damaged units or units that have been modified are not acceptable for repair in or out of warranty and will be returned as received.

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Table of Contents

Chapter 1 - Overview **1**
About This Manual 1
Precautions 1
Environmental Requirement 2
Storage Requirements 2
Microscopes, Lenses, and Tripods 2
Repairs 2
Cleaning 2

Chapter 2 - System Installation **3**
Introduction 3
Software Compatibility 3
Host Computer Requirements 3
Software Installation 3
Installing the USB card 4
Connecting the USB cable 5

Chapter 3 - Theory of Operation **6**
CMOS Image Sensor Structure 6
Digital Binning 7
Pixel Noise Filters 7
Trigger Modes 9
Expose Out Behaviour 9
Cooling 9

Chapter 4 - Basic Specifications **10**

Chapter 1 - Overview

About This Manual

The Moment CMOS user manual is divided into 3 chapters. Teledyne Photometrics recommends you read the entire manual before operating the camera to ensure proper use. The chapter contents are briefly described below.

Note: The information provided applies only to the Moment CMOS camera and is not applicable to any other Teledyne Photometrics camera.

System Installation – Instructions on how to connect the camera to the computer via the USB 3.2 Gen2 interface

Theory of operation – A basic overview of CMOS technology as used in the Moment CMOS

Basic specifications – specifications for the Moment CMOS

Precautions

The CMOS sensor and other system electronics are extremely sensitive to electrostatic discharge (ESD). To avoid permanently damaging the system, please observe the following precautions:

1. If using high-voltage equipment (such as an arc lamp) with the camera system, turn the camera power on last and when powering down, power the camera off first.
2. Use caution when triggering high-current switching devices (such as an arc lamp) near the system. The image sensor can be permanently damaged by transient voltage spikes. If electrically noisy devices are present, an isolated, conditioned power line or dedicated isolation transformer is highly recommended.
3. Always leave one inch of space around the camera for airflow.
4. Never open the camera. There are no user-serviceable parts inside the Moment CMOS camera. Opening the camera voids the warranty
5. Use only the interface card, cables and power supply designated for this camera system. Using non-Moment cables, interface cards or power supplies may result in unexpected errors or permanent damage to the system
6. Do not use a C-mount lens with optics that extend behind the lens flange

Environmental Requirements

The Moment CMOS camera should be operated in a clean, dry environment. The camera system should not be operated without being attached to a lens or microscope without proper airflow around the camera. The camera system's ambient operating temperature is 0°C to 30°C with 80% relative humidity, non-condensing.

Storage Requirements

The CMOS sensor and other system electronics are extremely sensitive to electrostatic discharge (ESD). To avoid permanently damaging the system, please observe the following precautions:

Microscopes, Lenses, and Tripods

The camera has two standard mounting options and can be coupled to any optical system or microscope that accepts a standard C-mount adapter for the Moment. The camera also allows you to install any lens that is compatible with either of these threaded video mounts if its optics do not extend behind the flange of the lens. Moment can be mounted to optical tables, tripods or custom stands using M3 screws threaded attachment points located near the front of the camera housing on all sides.

Repairs

Please save the original packing materials so you can safely ship the camera to another location or return it for repairs if necessary. The Moment CMOS camera system contains no user-serviceable parts. Repairs must be done by Teledyne Photometrics. Should the camera system require repairs, please contact Teledyne Photometrics Customer Service.

Note: Do not open the camera. Opening the Moment CMOS voids the warranty.

Cleaning

Clean exterior surfaces of the camera with a dry, lint-free cloth. To remove stains, contact Teledyne Photometrics Customer Service. To clean the camera's imaging window, use only a filtered compressed-air source. Hand-held cans are not recommended as they may spray propellant onto the window. Do not touch the window.

Chapter 2 – System Installation

Carefully review the Precautions section in the previous chapter before performing any of the procedures outlined in this chapter. Using a different cable or interface card may result in permanent damage to the system

Introduction

The Moment CMOS camera system includes the following hardware components:

- Moment CMOS Camera
- USB Interface Card
- USB cable
- Two single-line MMCX trigger cables
- USB memory device containing PVCAM library and drivers
- Quick Installation Guide

The Moment camera is powered over the USB 3.2 Gen2 connection. While it is recommended that the camera is operated via the USB interface card, the camera can also run on a PCs native USB 3.0 port. All of these hardware components should be included with the shipment. Keep all the original packing materials so you can safely ship the camera to another location or return it for service. If you have any difficulty with any step of the instructions, contact Teledyne Photometrics Customer Service.

Software Compatibility

Unless there is a preferred version specified by a third party software provider, the latest version of PVCAM is recommended for use with the Moment camera. The PVCAM SDK is available on the company website.

Host Computer Requirements

The host computer (PC) for Moment must meet the following minimum requirements:

- Windows 10 64-bit operating system
- 2.0 GHz or faster Intel processor: either Xeon or Core i7
- 8+ GB RAM
- 250+ GB serial ATA (SATA) HDD and/or >512 GB solid state drive (SDD) for high-speed imaging and storage
- 512+ MB slot-based ATI/NVIDIA video graphics card (i.e., not an "onboard/ integrated graphics" adapter)
- USB port for use with the USB memory device or Internet access to obtain the PVCAM library and interface drivers
- An open PCI-Express 4x (4 lane) interface slot or higher for use with the USB 3.2 Gen2 interface card

Software Installation

An appropriate Installation Guide is included as an insert with the camera. This guide provides step-by-step instructions for installing the camera interface software for Windows-based computers. Additional instructions are included for installing a PCI Express interface card in the computer. The Teledyne Photometrics USB memory device contains the following files:

- Manuals Directory — contains user manuals in PDF format.
- Customer Case Studies — application examples
- Imaging Software – a copy of Open Imaging's Microscopy Application: Micromanager
- Technical Notes – detailed background on advanced features

For a 64-bit Windows OS, install PVCam64_Setup_X_X_X_X.exe (latest version is on drive)

For a 32-bit Windows OS, install PVCam32_Setup_X_X_X_X.exe (latest version is on drive)

Follow the Installation Guide insert for the version of Windows being used. Reboot the computer when the installation is complete.

Installing the USB card

The USB 3.1 card included with the Moment camera ensures a stable connection and maximum data is able to be acquired from the camera.

Note: The model of USB card shipped with the camera may differ from the one shown in the photo. Please refrain from using other cards, as they may damage the camera.

Before attempting to operate the camera, first install this interface card into the PC with the following steps:

1. Shut down the PC
2. Unplug the PC from power mains and ensure the camera is turned off
3. Open the side of the computer to access the PCI and PCIe slots

4. Locate an available 4 channel or higher PCIe slot (marked x4). Refer to the PC's documentation to locate a suitable slot.

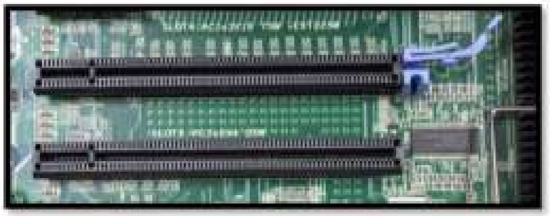


Figure 4

5. Holding the USB card and (being careful not to touch the board components or PCIe bridge pins) insert it with the proper orientation into the open slot. The card should slide into place with minimal resistance and snap when fully inserted.

Connecting the USB cable

Once the USB cable has been connected to the camera and host PC, the camera will power on. When using 3 meter active cables, it is important that proper USB cable orientation is used. Please refer to the quickstart guide with the camera or the USB stick for the most up to date instructions.

Chapter 3 – Theory of Operation

CMOS Image Sensor Structure

A major difference between traditional CCD sensors and CMOS sensors is the location where charge-to-voltage conversion of accumulated photoelectrons takes place. CCD sensors transfer the pixels accumulated signal in charge packets in "bucket brigade" fashion across the sensor to a common output node where charge is converted to a voltage. The voltage is then sampled using off-chip Analog-to-Digital Converters (ADC) and transferred to the PC as digital grey values.

While providing excellent quantitative photometry and very high image quality, the large number of transfers and sequential digitization of pixels results in low frame rates. This speed penalty increases with the number of pixels to be digitized. CMOS sensors leverage many of the same analog signal concepts used in CCDs, but places the output node circuitry inside each pixel. This eliminates the charge transfer process. To read the signal from a given row, the accumulated charge is converted to a voltage inside the pixel, then each pixel in the row is connected to the appropriate column voltage bus, where the on-chip ADCs covert the voltages to an 12-bit grey value. (Thus far, the on-chip ADCs available on CMOS sensors have limited dynamic range.) The parallel digitization of all pixels in a row provides CMOS devices with a tremendous speed advantage. Imagine a CCD with 2048x2048 pixels – and each pixel's voltage is measured in 1 µsec. To read a single row, 2048 voltage measurements are performed in serial fashion taking slightly longer than 2 ms,and when repeated for 2048 rows, the entire image takes over four seconds tobe digitized.

On this CMOS device – the entire 2200 voltage conversions needed to digitize a row happen in parallel. The sensor in the Moment CMOS camera takes parallelism even further by dividing the sensor into two halves, so that two rows of 2048 pixels can be measured at the same time. If the time to digitize a pixel remains at 1 us – the time to read the entire frame is now ~ 1 ms. In practice, the time saving is split between faster frame rates and slowing the rate of pixel measurement to reduce electronic noise. For example, if the time to measure a pixel was increased to 10 µsec to lower noise, the image sensor can still be read in 10 ms (for a maximum 100fps).

Of course, there are many challenges to obtaining the same analog performance from each of Moment's 7 million pixels, whereas a CCD has a single, common output node resulting in a uniform response. The most common problems are pixel-to-pixel non uniformity in gain and offset, random telegraph noise (RTN), and defective pixels with abnormal noise or dark current characteristics (hot pixels). Often solutions to these challenges are found in the digital domain, where Moment's advanced real time signal processing corrects each pixel for gain and offset variation using calibration at the factory. To address RTN and other pixel defects, real-time digital filters are used. These corrections are described further in this manual.

Digital Binning

CCD image sensors are capable of charge binning (combining adjacent pixels into one super pixel). This is accomplished as part of the charge transfer process and has the advantage of increasing signal to noise in read-noise limited situations, at the expense of spatial resolution.

The lack of a charge transfer process in CMOS devices means true charge binning is not available in currently available Scientific CMOS sensors. Even so, co-adding pixels is a convenient means to reduce image data, or increase signal by 4x and improve SNR by 2x as the noise from each pixel adds in quadrature. Moment includes 2x2 on-camera simulated binning, done on the FPGA. This mathematically combines signal from adjacent pixels and adjusts the sum so that the bias offset is only added one time.

Pixel Noise Filters

Note: The Moment CMOS camera ships with an optimized default setting for Real Time Pixel Noise Filtering. Normally these values do not need to be adjusted. Additionally, the features described in this section may not be controllable in the software application. This is an advanced usage section..

In the CMOS sensor section, it was noted that a drawback to current CMOS sensors is variability in pixel to pixel response. This variability falls into two categories, static variation in gain and offset and dynamic fluctuations that require real-time Pixel Noise Filters, also known as "Despeckling".

The static variation in gain and offset is measured and a correction factor is determined for every pixel. This fixed pattern noise is measured during manufacture and the corrections are stored in the camera. These corrections are then applied in real-time to each image.

The dynamic fluctuations must be detected and corrected in real-time. The Moment has several noise filters for this purpose. Defect detection is based on use of a conditional median filter. The 3x3 neighborhood surrounding a pixel is examined. If the pixel's value exceeds or falls below the median by a given amount, its value is replaced by the median. Four filters are available:

Real-time Filters for Random Telegraph Noise:

1. Despeckle Dark Low
2. Despeckle Bright Low

Real-time Filters for Bright (Hot) or Dark Pixels:

3. Despeckle Dark High
4. Despeckle Bright High

“Dark” filters work on the low side of the local median, while “Bright” filters work on the high side of the local median. The filter is only applied if the pixel’s value exceeds (or is below) a threshold expressed as a percent of the local median x100.

For example, a Despeckle Dark Low threshold of “97” indicates that a pixel that is 3% below the local median will be replaced with the local median. A Despeckle Bright High threshold of “300” indicates that a pixel that is 200% brighter than the local median will be replaced.

The intensity range where each filter operates can be set by a value known as “Minimum ADU AFFECTED”. Take the “Dark” filters for example – pixel values that fall below the Minimum ADU Affected will be operated on using Despeckle Dark Low, and pixel values that lie above the Minimum ADU Affected will be operated on using Despeckle Dark High settings.

Given the new terminology – a simplified way to visualize the region in which each filter operates is shown below:

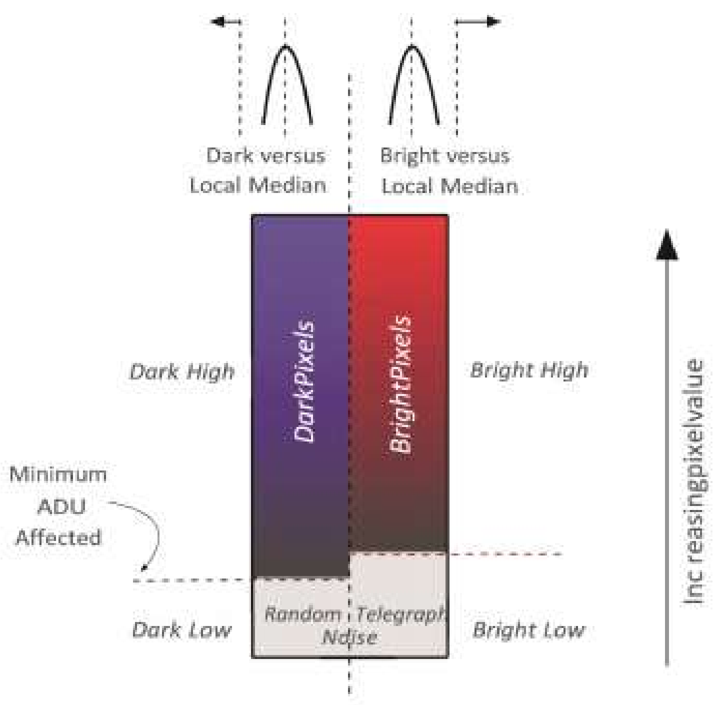


Figure 8: Pixel Noise Filter

The general principle for setting the pixel noise filters is to use as little filtering as possible. Often the best way to determine this is viewing a real-time histogram with log scaling of the frequency. For setting “Dark Low” and “Bright Low”, block any light from reaching the sensor and examine the bias histogram. This allows viewing the histogram’s tail, where the effect of the filters can be seen. Adjust the filters to trim the non-Gaussian tails from the distribution. For “Dark High” and “Bright High”, observe the image with flat, even illumination in the expected range to be observed. Adjust “Bright High” to eliminate most of the bright speckles, and adjust “Dark High” to eliminate any dark speckles that might appear.

Trigger Modes

Timed Mode

Timed mode is the default triggering mode for Moment. This means, the software/application initiates the start of a sequence of acquisitions. Once initiated, each frame captured in the sequence is controlled by the internal timing generators of the camera. Camera settings, expose out behaviour and sequence size are set in the software application prior to acquiring the sequence. Timed mode is used when synchronization with other devices is either not required or is controlled independently through the software.

Expose Out Behaviour

Edge Mode

Like Trigger-First Mode, Edge Mode requires a hardware trigger but this time for every frame. The rising edge of the external trigger initiates capture of a single frame. Each frame requires an external trigger from the I/O connector. Camera settings, expose out behaviour and sequence size is set in the software application prior to acquiring the sequence.

Cooling

The Moment is a global shutter camera. This means that all pixels are electronically shuttered to be receiving light at the same time. As a result, the expose out signal, designed to trigger light sources to only illuminate when the camera is ready, demonstrates straightforward behaviour. The benefit of a global shutter is that no rolling shutter effects are present, such as image distortion on moving samples.

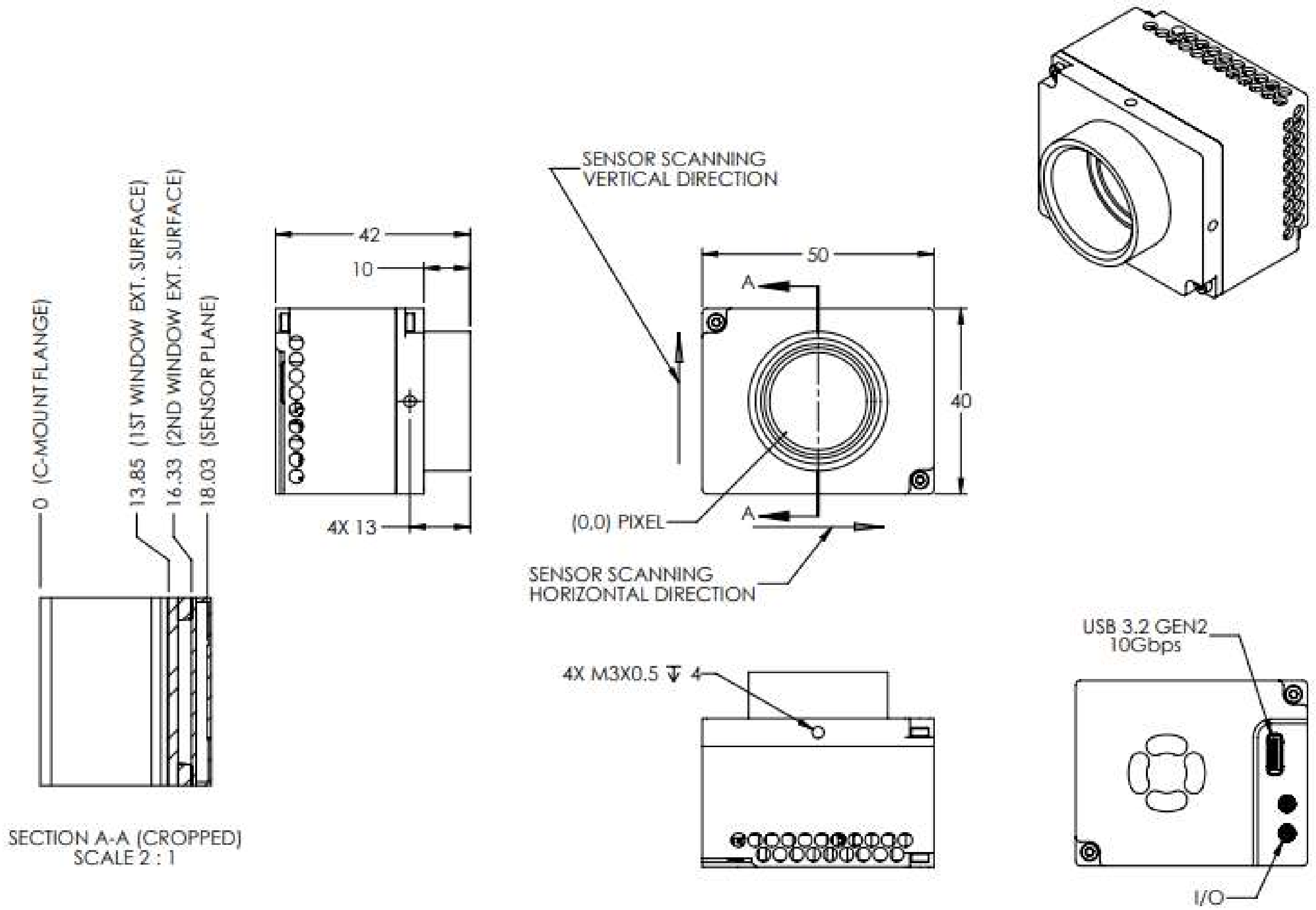
The Moment CMOS is an uncooled camera. A micro-fan is part of the camera assembly, and is used to move heat away from the camera boards. It is advised to have the camera attached to either a lens or a microscope while the camera is in use.

Chapter 4 – Basic specifications

Specifications	Camera Performance
Sensor	Photometrics Sony-based Scientific CMOS
Active Array Size	3200 x 2200 (7 Megapixel)
Pixel Area	4.5µm x 4.5µm
Sensor Area	14.4mm x 9.9mm, 17.5mm diagonal
Peak QE%	73%
Read Noise	2.2 e^-
Full-Well Capacity	8200e^-
Framerate (full-frame)	50 fps
Bit Depth	12-bit
Shutter Type	Global Shutter
Cooling	Uncooled
Interface	USB 3.2 Gen 2 (10 Gbps)
Triggers	1 Input 1 Output

Frame Rate	
Array Size	**Speed**
3200 x 2200	51
3200 x 1100	100
3200 x 550	193
3200 x 275	353
3200 x 8	1814
3200 x 2	2074

Chapter 4 – Basic specifications



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