TELEDYNE PHOTOMETRICS
Everywhere**you**look™

KINETIX22

High Speed, Back-Illuminated sCMOS

22 mm Field of View
6.5 µm Pixels
5.7 Megapixel
500 Frames Per Second
95% Quantum Efficiency

LIMITED WARRANTY

Teledyne Photometrics ("Teledyne Photometrics," "us," "we," "our") makes the following limited warranties. These limited warranties extend to the original purchaser ("You," "you") only and no other purchaser or transferee. We have complete control over all warranties and may alter or terminate any or all warranties at any time we deem necessary.

Basic Limited Three (3) Year Warranty

Teledyne Photometrics warrants this product against substantial defects in materials and/or workmanship for a period of up to three (3) 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.

Limited One (1) Year Warranty on Refurbished or Discontinued Products

Teledyne Photometrics warrants, with the exception of the CMOS or CCD image sensor device (which carries NO WARRANTIES EXPRESS OR IMPLIED) this product against defects in materials or workmanship for a period of up to one (1) year after shipment. During this period, Teledyne Photometrics will repair or replace, at its sole option, any defective parts, without charge to you. You must deliver the entire product to the Teledyne Photometrics factory or, at our option, a factory-authorized service center. You are responsible for the shipping costs to return the product to Teledyne Photometrics. International customers should contact their local Teledyne Photometrics representative/distributor for repair information and assistance or visit our technical support page at www.photometrics.com.

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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Teledyne Photometrics warrants all of our manufactured software discs or memory devices to be free from substantial defects in materials and/or workmanship under normal use for a period of one (1) year from shipment. Teledyne Photometrics does not warrant that the function of the software will meet your requirements or that operation will be uninterrupted or error free. You assume responsibility for selecting the software to achieve your intended results and for the use and results obtained from the software. In addition, during the one (1) year limited warranty, the original purchaser is entitled to receive free version upgrades. Version upgrades supplied free of charge will be in the form of a download from the Internet. Those customers who do not have access to the Internet may obtain the version upgrades on a USB memory device from our factory for an incidental shipping and handling charge.

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.

Your Responsibility

The above Limited Warranties are subject to the following terms and conditions:

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 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 manufacturers' 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.

All warranties implied by state law or non-U.S. laws, including the implied warranties of merchantability and fitness for a particular purpose, are expressly limited to the duration of the limited warranties set forth above. With the exception of any warranties implied by state law or non-U.S. laws, as hereby limited, the forgoing warranty is exclusive and in lieu of all other warranties, guarantees, agreements, and similar obligations of manufacturer or seller with respect to the repair or replacement of any parts. In no event shall Teledyne Photometrics' liability exceed the cost of the repair or replacement of the defective product or part.

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**TELEDYNE
PHOTOMETRICS**
Everywhere**you**look"

Declaration of Conformity

Photometrics, Tucson, AZ, U.S.A.

We declare under our sole responsibility the compliance of the product with EN 61326-1, EN 55011:2009, EN 61000-3-2, EN 61000-3-3, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6, EN 61000-4-11

Any modification of the product, not authorized by us, will invalidate this declaration.

Product Name: Kinetix

Identification: Kinetix Camera

Directive: Electromagnetic Compatibility (2014/30/EU).

     Low Voltage Directive (2014/35/EU)

Test acc. To: FCC Part 15, Subpart B
     EN 61326-1:2013
     EN 55011:2009, EN 61000-3-2
     EN 61000-3-3, EN 61000-4-2
     EN 61000-4-3, EN 61000-4-4
     EN 61000-4-5, EN 61000-4-6
     EN 61000-4-11

The product is marked with:

CE   FC

Date: **May 11, 2021**

Yogesh Gandhi
Production & Quality Manager
Teledyne Photometrics

v

ADCA-D169-CE83-4E19

방송통신기자재등의 적합등록 필증

Registration of Broadcasting and Communication Equipments

상호 또는 성명 *Trade Name or Registrant*	**Teledyne Photometrics**
기자재명칭(제품명칭) *Equipment Name*	**카메라**
기기부호/추가 기기부호 *Equipment code* */Additional Equipment code*	**IMI61**
기본모델명 *Basic Model Number*	**01-KINETIX-M-C**
파생모델명 *Series Model Number*	**01-KINETIX-1-M-C, 01-KINETIX-22MM-M-C,** **01-KINETIX-SX-M-C, 01-KINETIX-2-M-C**
등록번호 *Registration No.*	**R-R-Tpm-01-KINETIX-M-C**
제조자/제조국가 *Manufacturer/Country of Origin*	**Teledyne Photometrics / 캐나다**
등록연월일 *Date of Registration*	**2020-12-29**
기타 *Others*	

위 기자재는 「전파법」 제58조의2 제3항에 따라 등록되었음을 증명합니다.

It is verified that foregoing equipment has been registered under the Clause 3, Article 58-2 of Radio Waves Act.

2021년(Year) 10월(Month) 21일(Day)

국립전파연구원장

Director General of National Radio Research Agency

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위반시 과태료 처분 및 등록이 취소될 수 있습니다.

Table of Contents

Chapter 1 – Overview

About This Manual

The Kinetix22 Scientific CMOS Camera User Manual is divided into six chapters and three appendices. Teledyne Photometrics recommends you read the entire manual before operating Kinetix22 to ensure proper use. The chapters that follow the Overview are briefly described below.

Note: The information in these chapters applies only to the Kinetix22 camera and is currently not applicable to any other Teledyne Photometrics camera.

- **System Installation** – Instructions for connecting the Kinetix22 camera to a computer via the PCI Express interface card or the USB 3.2 interface.
- **Theory of Operation** – A basic overview of Scientific CMOS camera technology as used in the Kinetix22 camera.
- **Operating Features** – Kinetix22 features and how to optimize them for sensitivity, speed, dynamic range; how to use the different trigger modes.
- **Troubleshooting** – Answers to common camera system questions.
- **Basic Specifications** – Specifications for Kinetix22 system components.

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:

- 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.
- Never connect or disconnect any cable while the system is powered on.
- The camera's power should be switched off before disconnecting any camera system cables. However, it is not necessary to power off the computer to detach the cables.
- 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.
- Always leave one inch of space around the camera for airflow.
- Do not operate the camera without cooling (air or liquid).
- Never open the camera. There are no user-serviceable parts inside the Kinetix22 camera. Opening the camera voids the warranty.

- Use only the PCI Express interface card, cables, and power supply designated for this camera system. Using non-Kinetix22 cables, PCI Express interface cards, or power supplies may result in unexpected errors or permanent damage to the system.
- Do not use a C-mount lens with optics that extend behind the lens flange.

Environmental Requirements

The Kinetix22 camera system should be operated in a clean, dry environment. The camera system's ambient operating temperature is 0°C to 30°C with 80% relative humidity, non-condensing.

Storage Requirements

Store the Kinetix22 camera system in its original containers. To protect the system from excessive heat, cold and moisture, store at an ambient temperature between -20°C and 60°C with a relative humidity of 0% to 90%, noncondensing.

Microscopes, Lenses, and Tripods

The camera has standard threaded adapter mounts and can be mounted to any microscope that accepts a standard C-mount adapter. The camera also allows you to install any lens that is compatible with the standard threaded mounts as long as its optics do not extend behind the flange of the adapter. Kinetix22 can be mounted to optical tables, tripods, and copy stands using the eight ¼-20 threaded attachment points located near the camera front on all sides. A crosshair indicates the location of the sensor for optical alignment purposes.

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 Kinetix22 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 Kinetix22 camera 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.

Note: Carefully review the Precautions section in the previous chapter before performing any of the procedures outlined in this chapter. Again, use only a Kinetix22 PCI Express data cable and Kinetix22 PCI Express interface card with the camera. Using a different cable or interface card may result in unexpected errors or permanent damage to the system.

Introduction

The Kinetix22 camera system includes the following hardware components:

- Kinetix22 Scientific CMOS Camera
- USB 3.2 A to C data cable, 1 m
- USB 3.2 C to C data cable, 3 m
- A 12V/10A DC power supply with international power cord set
- I/O to 8 BNC trigger breakout cable, part number CBL-IO-8-BNC
- USB memory device containing PVCAM library and drivers
- *Quick Installation Guide*
- PCI Express (PCIe) interface card
- PCI Express data cables (two identical cables)
- USB 3.2 10 Gbps interface card

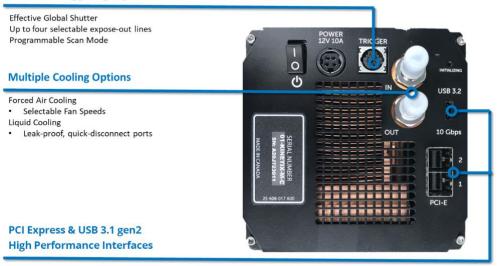Kinetix22 system components are linked by two PCI Express data cables or a USB 3.2 data cable and controlled by the host computer system. These hardware components should be included with the shipment. Keep all the original packing materials so you can safely ship the camera to another location or return it for service.

If you have any difficulty with any step of the instructions, contact Teledyne Photometrics Customer Service.

Getting to Know Kinetix22

Highlights of the Kinetix22 camera are shown below. The Kinetix22 package includes the PVCAM drivers designed to allow you to use this camera with a variety of third-party imaging software. For a list of supported software, visit the Teledyne Photometrics website.

Advanced Triggering Capabilities

Effective Global Shutter
Up to four selectable expose-out lines
Programmable Scan Mode

Multiple Cooling Options

Forced Air Cooling
• Selectable Fan Speeds
Liquid Cooling
• Leak-proof, quick-disconnect ports

**PCI Express & USB 3.1 gen2
High Performance Interfaces**

- USB 3.2 10 Gbps Data Connection
- PCI-E: High Speed Connection
- In/Out: Liquid Cooling Connections
- Initializing: LED blinking indicates the camera is booting up
- Power Switch: Turns the camera on and off
- Trigger: Hirose HR10A-10R-10S for use with Teledyne Photometrics trigger to BNC breakout cable CBL-IO-8-BNC
- Power in: Connection to external 12V/10A DC power supply

Software Compatibility Requirements

Unless there is a preferred version specified by a third-party software provider, the latest version of PVCAM is recommended for use with Kinetix22: https://www.photometrics.com/support/download/pvcam.

Host Computer Requirements

The host computer (PC) for Kinetix22 must meet the following *minimum* requirements:

- Windows 10 64-bit operating system
- 3.0 GHz or faster Intel processor: either Xeon or Core i7; 4 or more cores
- 16+ GB DDR3 RAM or higher (Teledyne Photometrics recommends matching the number of memory modules with the number of CPU-supported memory channels)
- 256 GB or larger serial ATA (SATA) SSD for the operating system

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- 1 GB slot-based ATI/NVIDIA video graphics card
- Internet access to obtain the PVCAM library and interface drivers
- USB 3.2 or Thunderbolt port for use with the USB 3.2 interface
- An open PCI Express 8x Gen 3 interface slot or higher for use with the PCIe interface card

Note: To achieve *optimal* performance, see our latest recommended PC specifications at https://www.photometrics.com/support/recommended-pc-specifications.

Software Installation

An appropriate *Quick Installation Guide* is included as an insert with the Kinetix22 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 the Free Open Source Software Application, Micro-Manager

- Technical Notes – detailed background on advanced features

- For a 64-bit Windows OS, install the PVCAM driver

- Follow the *Quick Installation Guide* insert for the version of Windows being used and then reboot the computer when the installation is complete

Installing the PCI Express Interface Card

As CMOS cameras have developed, the amount of data generated from these products has exceeded the current capabilities of USB interfaces. The Kinetix22 CMOS camera platform provides both USB 3.2 for convenience and a PCI Express interface to ensure that the interface is capable of sustaining the required bandwidth of the camera.

Instructions for Installing the High Speed PCI Express Interface Card:

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Note: The model of PCIe card shipped with the camera may differ from the one shown in the photo.

Before attempting to operate the camera, first install this interface card into the PC via 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 8-channel or higher PCIe slot (marked x8). Refer to the PC's documentation to locate a suitable slot.

User Tip: The PC may have motherboard slot information on the side cover.

5. Hold the PCIe card (being careful not to touch the board components or PCIe bridge pins) and insert it, properly orientated, into the open slot. The card should slide into place with minimal resistance and click when fully inserted.

PCIe card inserted into a 16-channel PCIe slot.

PCIe card inserted into an 8-channel PCIe slot. Note the remaining free-floating PCIe slots.

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The default DIP Switch pin settings for the PCIe card are shown below. This will allow the user to run one or two cameras off the PCIe card at the full speeds available.

Connecting Kinetix22 to PCI Express Bus

The two Kinetix22 camera data cables are identical, quick-insertion, quick-release cables that connect the interface card and the camera. One of these cables is shown below.

Note: The PCIe data cables' connectors can only be inserted into the PCIe ports when correctly oriented; do not force the connectors. If a connector does not insert, simply turn the connector over and retry.

To ensure proper system performance, one of the cables should be used to connect the camera's PCIe port 1 to the PCIe interface card's port 1. (Either end of the cable can be plugged into either device.) The other cable should be used to connect the camera's PCIe port 2 to the PCIe interface card's port 2. (Again, either end of the cable can be plugged into either device.) See the following two figures. Here, both ends of one cable have been wrapped with white tape to differentiate it from the other cable.

PCIe cables inserted into camera's PCIe ports.

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PCIe cables inserted into PCIe interface card's ports.

User Tip: To avoid any future confusion, add a marker of some sort, like electrical tape, to each end of one cable during camera installation and then confirm that port 1 on the camera is connected to port 1 on the PCIe card, and that port 2 on the camera is connected to port 2 on the PCIe card.
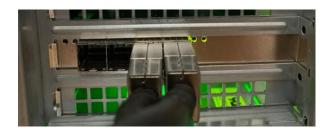
With the PCIe data cables properly connected, it is time to power on the computer:

1. Verify that the power switch on the side of the camera is in the off position.
2. Connect the power supply to the Power connector on the rear of the camera.
3. Plug the power cord into the power supply and then into a suitable wall outlet.
4. Switch on the computer and let it go through its normal startup process.
5. Turn on the Kinetix22 and allow it 30 seconds to boot before starting software.

User Tip: The power supply and connector used by the Kinetix22 camera are each a common type. However, Teledyne Photometrics carefully selects power supplies for optimum noise performance, EMI compliance, and stability. Do not swap power supplies with other lab equipment even though they may meet the connector, voltage, and ampere requirements of Kinetix22.

Verify the camera link has been established, which is confirmed by two green LED lights on the PCIe card.

If one or both LEDs are orange instead of green, make sure the cables are connected in the right ports order and are undamaged.

Connecting Kinetix22 with USB

The Kinetix22 camera's USB 3.2 10 Gbps interface (formally known as USB 3.1 Gen 2) is ubiquitous and easy to use. To use the interface, the PC must have an open USB 3.2 or Thunderbolt port.

User Tip: USB devices sharing the same bus as Kinetix22 contend for available bandwidth, potentially causing the camera to drop frame rate. For this reason, Teledyne Photometrics recommends isolating the camera to its own USB 3.2 root hub as shown in the Windows Device Manager. A method for creating an independent root hub in computers with many USB devices is to install a PCI Express-based USB 3.2 interface card for use with the camera. We do not recommend connecting Kinetix22 to USB 3.0.

Before connecting the USB 3.2 cable as directed below, note that the ends of the cable are different for the camera and the PC (and thus require a specific orientation). Even for the USB 3.2 C to C cable, there's a preferred end for the computer (host) and camera (sink). The camera has a USB-C connector, and the computer will typically have either a USB-A or USB-C connector. Do not force insertion when connecting the cable. If significant resistance is encountered then stop, reexamine the connection, and, if correct, retry.

You are now ready to connect the USB 3.2 cable:

1. With the camera off, connect the USB 3.2 cable to the camera and host computer.

2. Power the camera on.

3. Wait 30 seconds before launching the application. An LED on the back of the camera will stop blinking when the camera is initialized and ready to communicate.

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Introduction

Backside-illuminated scientific CMOS (BSI Scientific CMOS) sensors are a recent but rapidly maturing development in image sensor technology. Boasting near-perfect 95% quantum efficiency (QE), they are able to provide the highest levels of sensitivity. New cameras can now leverage these high-QE sensors to offer a combination of low read noise, high full well capacity, and fast readout rates that is ideal for modern low-light imaging.

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 (ADCs) 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 place 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 convert the voltages to a grey value.

The parallel digitization of all pixels in a row provides CMOS devices with a tremendous speed advantage. Imagine a CCD with 2400 x 2400 pixels – and each pixel's voltage is measured in 1 μsec. To read a single row, 2400 voltage measurements are performed in serial fashion taking slightly longer than 2.4 msec, and when repeated for 2400 rows, the entire image takes more than 10 seconds to be digitized.

On a CMOS device, the entire 2400 voltage conversions needed to digitize a row happen in parallel. If the time to digitize a pixel remains at 1 μsec, the time to read the entire frame is now 2.4 msec. 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 5 μsec to reduce noise, then the image sensor can still be read in 12 msec (for a maximum 83 fps).

Of course, there are many challenges to obtaining the same analog performance from each of the Kinetix22 camera sensor's 5.8 million pixels. Whereas a CCD has a single, common output node resulting in a uniform response, the most common hurdles for a CMOS device 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 the solutions to these challenges are found in the digital domain, where the Kinetix22 camera system'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.

Gain Combining and Bit Depth

As discussed in the previous sections, the column ADCs in scientific CMOS devices have limited dynamic range. This challenge is addressed by making two measurements of the accumulated charge in each pixel – the first with very high sensitivity but limited to a maximum signal of approximately 1000 electrons, and the second with reduced sensitivity but capable of measuring signals up to the pixel's 15,000 electron full well capacity.

Combining the two measurements into a single 16-bit value is the function of the digital "gain combiner." This mathematical operation is performed on the camera's FPGA. The result is a single gain of approximately 0.25 e-/ADU.

In practice, Kinetix22 offers both a combined 16-bit ADC output as well as 12-bit and 8-bit single ADC output. The 12-bit Sensitivity Mode uses the same approach as 16-bit Dynamic Range Mode but combines two high-gain measurements to reduce the camera read noise. In addition, the 12-bit and 8-bit modes can read two rows simultaneously. The camera's 16-bit Sub-Electron Mode also samples two rows simultaneously, but measures the intensity of each pixel 8x, explaining the latter mode's modest frame rate.
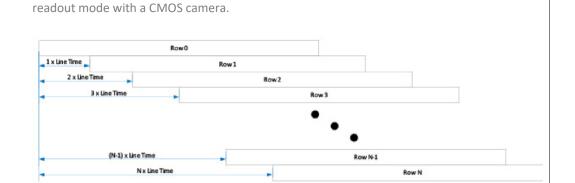
Rolling and Global Shutter Readout

Rolling Shutter and Global Shutter are the two primary operating modes of CMOS image sensors. In Global Shutter readout, a global charge-clearing mechanism begins the exposure period for all pixels. Each pixel accumulates signal charge until the exposure period ends. At this point, the accumulated charge is transferred and converted to a voltage in the pixel's output node, ending the exposure.

The strength of the Global Shutter approach is that all pixels are exposed at the same instant in time – an important attribute when imaging fast-moving objects. The downside of this approach is the sensor has two phases, an active image accumulation phase and a subsequent readout phase. As the phases are not overlapped in time, the maximum achievable frame rate is lower.

In Rolling Shutter readout, exposure and readout are overlapped. This is accomplished by beginning the exposure one row at a time, then starting the readout one row at a time. (The row being digitized "rolls" through the sensor.)

For Kinetix22, the time to digitize a single row is 5.00 µsec in Dynamic Range Mode. Digitizing 2400 rows of pixels, the time delay from the top to the middle of the sensor is approximately 12 msec. Since readout and exposure are overlapped, the sensor achieves a maximum frame rate of 83 fps. In the 12-bit mode (Sensitivity), while two rows are read out simultaneously, the row time is equal to 4.7065 µsec, providing a maximum frame rate of 88 fps. The 8-bit mode (Speed) has a row time equal to 0.836 µsec, providing a maximum frame rate of 498 fps.

when read out 1 line at a time	Dynamic Range Mode	Speed Mode	Sensitivity Mode	Sub-Electron Mode
Line Time (µsec/line)	5.00	0.836	4.7065	80.1

Line times for the various modes of the Kinetix22 camera.

The graphic below depicts the time delay between each row of pixels in a Rolling Shutter readout mode with a CMOS camera.

Rolling Shutter exposure row-by-row exposure start/end offset.

The downside of Rolling Shutter readout is that changes in the scene on similar timescales are distorted, as each row samples the image at different times. This is the well-known "rubber band" effect. It can appear in fluorescence microscopy as shaded illumination when rapidly changing wavelengths.

To maintain the benefit of Rolling Shutter readout and eliminate rolling shutter artifacts, external illumination can be gated on when all rows are being simultaneously exposed, and off during the readout phase. This external triggering mode, used in combination with high speed light sources (e.g., lasers, LEDs), achieves a pseudo global shutter effect. This triggering mode is described in the device synchronization section of this manual.

Digital Binning

CCD image sensors are capable of charge binning (i.e., 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 current 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.

The Kinetix22 system includes symmetric and asymmetric on-camera digital binning of up to 4 x 4 pixels. This mathematically combines signal from adjacent pixels and adjusts the sum so that the bias offset is only added one time.

Sensor Clearing

In order to capture the highest signal-to-noise ratio possible, it is important that scientific cameras minimize any signal that's not derived from the sample. One contribution to this background signal is the buildup of charge prior to an exposure, which includes any light still reaching the sensor as well as thermally generated sensor dark current. To eliminate this pre-acquisition charge accumulation, most CCD and CMOS cameras clear the sensor one or more times prior to exposing the sensor to light. This can be done using a "fast" readout that is subsequently discarded.

Unlike CCDs, there is limited benefit to performing multiple pre-exposure clearing cycles with CMOS, because each pixel is reset as part of the normal readout process, and the charge transfer registers that can hold residual signals are not present.

Bias Offset Settings

Scientific cameras produce a fixed artificial signal offset known as bias offset. This grayscale offset is present in all pixel values, even when no light is falling on the sensor and the exposure time is set to zero. Bias offset prevents clipping of the camera read noise and preserves quantitation even down to signals of a few electrons per pixel.

The factory default bias level is approximately 100 ADU in Dynamic Range Mode and Sensitivity Mode. The default bias level is approximately 20 ADU in Speed Mode and approximately 1000 ADU in Sub-Electron Mode.

If supported by the software application being used, the bias level can be altered. However, we do not recommend changing this value because the preset values for the Despeckle Pixel Noise Filters are set with this value.

For quantitation, many users subtract an average bias image, calculated at the start of each experimental run. This can also be used to monitor for light leaks and other systematic effects that can impact experimental results.

Pixel Noise Filters

Note: The Kinetix22 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 or may not be controllable in the software application of choice.

In contrast to CCD technology, each pixel in a CMOS camera has unique electronics that can cause pixel-to-pixel variability. This variability falls into two categories: (1) static variation in gain and offset, and (2) dynamic fluctuations called Random Telegraph Noise (RTN) that require real-time filtering, 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. The corrections are then applied in real-time to each image.

The dynamic fluctuations must be detected and corrected with each acquisition. The Kinetix22 camera has noise filters for this purpose. Detection of a transiently high or low pixel value due to RTN is based on comparison to the median value of the neighboring 3x3 pixel array. If an individual pixel's value exceeds or falls below the median by a certain percentage, its value is replaced by the median value.

We find this works well to filter out RTN but can lead to misleading results should the sample contain point sources that image to a single pixel. For example, sub-diffraction point sources should be detected across multiple pixels in the neighboring 3x3 group when sampling at Nyquist. However, spatial under-sampling due to a mismatch in pixel sampling versus optical resolution might cause signal to localize to a single pixel. In this circumstance the signal might be filtered as if it were due to RTN.

Four filters are available:

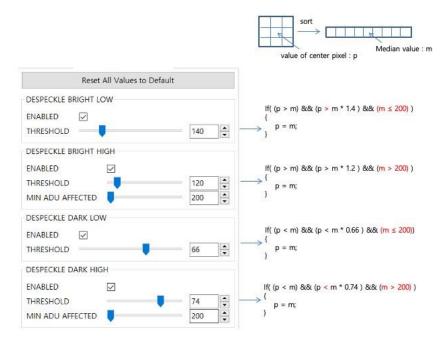Real-time filters for Random Telegraph Noise:

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

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"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 x 100.
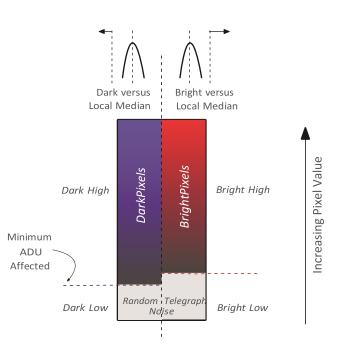

For example, in the figure above, a Despeckle Dark Low threshold of "66" indicates that a pixel that is 34% below the local median will be replaced by the local median. A Despeckle Bright High threshold of "120" indicates that a pixel that is 20% brighter than the local median will be replaced.

The intensity range in which each filter operates can be set by a value known as "Minimum ADU Affected." With the "Dark" filters, for example, pixel values that fall below the Minimum ADU Affected will be operated on using Despeckle Dark Low, whereas pixel values that lie above the Minimum ADU Affected will be operated on using Despeckle Dark High settings.

Given this terminology, a simplified way to visualize the region in which each filter operates is shown in the following figure.

Generally, the optimal values for these filters are set at the factory. However, some experimental approaches utilize much better postprocessing noise-reduction algorithms than can be implemented in-camera. Should you find the need to alter the filter strength, 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 by 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 of 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.
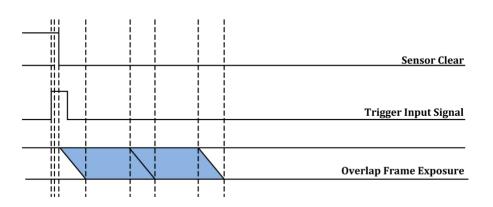
Although they can be set independently, we do not recommend changing the Minimum ADU Affected. This value will have been set at the factory to approximately 1.5x the bias level to ensure the "Low" filters are operating on RTN noise.

Chapter 4 – Operating Features

Introduction

This section explains the Kinetix22 camera system's different modes of operation and the best modes to optimize imaging performance.

Modes and Gain States

Kinetix22 has four modes:

- Dynamic Range
- Sensitivity
- Speed
- Sub-Electron

The Dynamic Range (16-bit) Mode provides the best balance between full well capacity and noise performance. However, it provides lower frame rates than the single gain outputs.

The Sensitivity (12-bit) Mode provides low read noise performance, while maintaining moderately fast frame rates. The signal is sampled twice by configuring both the amplifiers to have high sensitivity. This mode trades off dynamic range for lower read noise.

The Speed (8-bit) Mode provides the highest frame rates.

The Sub-Electron (16-bit) Mode uses two approaches to generate data similar to that generated by EMCCD sensors but without the complications of the extra noise associated with on-chip amplification. Measuring the internal signal from a pixel multiple times reduces the error in the measurements, as indicated by the low read noise of the camera in this mode. Setting the conversion gain to a highly sensitive value spreads low-signal changes across a greater range of grey values in order to provide high contrast in the final image.

Clearing Mode

Kinetix22 provides a single clear mode, "Clear Auto." The camera is continuously clearing the sensor while there are no images being acquired. This eliminates unnecessary sensor clearing and maximizes frame rates.

The following waveforms show how the overlap behavior of "Clear Auto" functions for the Kinetix22 camera:

Regions of Interest

Regions of Interest (ROIs) are image subregions selected by the user to be captured and delivered to the host PC in place of the full image. This can substantially increase frame rates and lower the amount of data that needs to be processed.

Frame rate increases as the number of rows contained in the ROI decreases. By reducing this number of rows, frame rates above 1000 fps are achievable. As a result of the scientific CMOS sensor architecture, if any pixel in a row is part of the ROI, the entire row is digitized. Reducing the number of columns in the ROI does not improve the frame rate of the camera but it does reduce the amount of data acquired, saving computer resources and processing time.

Programmable Scan Mode

Applications such as light sheet microscopy and digital slit confocal microscopy often utilize the rolling shutter readout of sensors to enhance image quality. Programmable Scan Mode (PSM) allows the user to add delays to rows while the Kinetix22 sensor is exposing. This acts like a full-width region of interest that rolls across the columns of the sensor using the rolling shutter readout to build the final image. Should the region of interest coincide with the focus of illumination light, as in certain types of light sheet microscopy or line scan illumination, out-of-focus or scattered light collection can be minimized.

In rolling shutter CMOS cameras, the exposure time for a line is defined by a reset signal followed by a readout signal. The time difference between these signals is equal to the exposure time. In Programmable Scan Mode, delays are added before the reset signal. This modifies the propagation of reset and readout signals down the sensor, providing control over the number of rows with pixels collecting signal.

For the 16-bit Dynamic Range (DR) Mode of the Kinetix22 camera, the reset and readout signals propagate at a rate of 1 row per line time. However, for non-DR ports of the Kinetix22 camera, these signals propagate at a rate of 2 rows per line time. In 16-bit Dynamic Range Mode, the camera takes advantage of the two data channels available in the sensor to read a single row with different gains. In non-DR modes, both channels are used, but to read consecutive rows. This 1 vs. 2 line readout affects the timing of PSM delays when setting conditions, as discussed below.

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Control of this function is provided via a variety of settings. The view of these settings in Micro-Manager is displayed below.

Camera-1-ScanDirection	Down
Camera-1-ScanDirectionReset	Yes
Camera-1-ScanLineDelay	1
Camera-1-ScanLineTime	10,260,000
Camera-1-ScanMode	Auto
Camera-1-ScanWidth	Auto
Camera-1-SerialNumber	Line Delay
Camera-1-ShutterCloseDelay	Scan Width

Auto

When Programmable Scan Mode is set to Auto, the scan delay is 0, giving a reset and readout signal propagation of 1 row per line time (2 rows per line time for Kinetix22 non-DR modes). This is the default mode, with no delays added to normal rolling shutter output.

Line Delay

When ScanMode is set to Line Delay, a scan delay can be added, slowing the propagation of the reset and readout signals. The delay is set using ScanLineDelay. Delay is added in increments of line time (2 line times for Kinetix22 non-DR modes). In this mode, scan width becomes read only.

Effective line time using 16-bit DR is calculated as:

$$Line\ Time_{Effective} = Line\ Time_{Sensor} + (Line\ Time_{Sensor} \times ScanLineDelay\ Value)$$

Effective line time using non-16-bit DR is calculated as:

$$Line\ Time_{Effective} = 2x\ Line\ Time_{Sensor} + (Line\ Time_{Sensor} \times ScanLineDelay\ Value)$$

where the ScanLineDelay value is an even number. If an odd number of lines is input, the value is rounded up to the next even number. This rounding is only valid for the Kinetix22 non-Dynamic Range ports.

Using the camera line times in these examples, a scan delay of 3 line times for the Kinetix22 16-bit DR port yields:

$$Line\ Time_{Sensor} = 5.00\ \mu sec$$
$$Scan\ Line\ Delay = 1\ Line\ Time$$
$$Scan\ Line\ Time_{(nsec)} = (1 + 3) * 5.00\ \mu sec = 20.00\ \mu sec$$

Using these settings, 4 rows of pixels are actively integrating signal.

A second example, using PSM with 12-bit Sensitivity Mode, illustrates the consequences of the dual-line read behavior. Using a scan delay of 10 lines yields:

$$Line\ Time_{Sensor} = 4.7065\ \mu sec$$
$$Scan\ Line\ Delay = 10\ Line\ Times$$
$$Scan\ Line\ Time_{(nsec)} = (2 + 10) * 4.7065\ \mu sec = 56.478\ \mu sec$$

Using these settings, 12 rows of pixels are actively integrating signal.

Note: Line Times are commonly presented in units of microseconds, but ScanLineTime is reported via software in units of nanoseconds.

Scan Width

When Programmable Scan Mode is set to Scan Width, the number of rows containing active pixels can be set directly. In 16-bit Dynamic Range Mode, the Scan Width is equal to the input number. Odd and even widths are allowed. In the other ports of the Kinetix22 camera, which read 2 lines at a time, only even numbers of rows are used. Odd numbers of rows are incremented by 1 to the next highest even number.

The Kinetix22 line time values required to use the equations above are presented in the table below. Here are the effective line times (in μsec) for use in PSM calculations:

Type of Readout	16-bit Dynamic Range	12-bit Sensitivity	8-bit* Speed	16-bit* Sub-Electron
Single line	5.00 μsec	-	-	-
Dual line	-	4.7065 μsec	-	-

As of firmware version 30.29.03 neither the 8-bit Speed Mode nor 16-bit Sub-Electron Mode is supported in PSM.

Scan Direction

Programmable Scan Mode also provides control over the direction of the scan. The available options are as follows:

- Down

    A scan direction of Down is the default readout direction for all sCMOS cameras. The rolling shutter starts at the topmost row of the sensor and propagates downwards toward the bottommost row.

    Each subsequent frame acquisition restarts at the topmost row.

- Up

    A scan direction of Up inverts the direction of readout. The rolling shutter starts at the bottommost row and propagates upwards toward the topmost row.

    Each subsequent frame acquisition restarts at the bottommost row. The image orientation when acquired in this mode will not be inverted and will be consistent with the Down scan direction.

- Down-Up Alternate

A scan direction of Down-Up Alternate alternates the direction of acquisition. The rolling shutter starts at the topmost row and propagates downwards toward the bottommost row. For the next frame, the rolling shutter will begin at the bottommost row and propagate upwards toward the topmost row. The acquisition will continue to alternate the readout direction between frames.

When using this mode, the orientation of an object in an image will be the opposite of that from Down orientation.

Device Synchronization (Triggering)

Kinetix22 offers several methods of integrating with external hardware devices. A 10-pin, Hirose HR212-10RC-10SDL(74) connector is located on the back of the camera for trigger input/output operations.

The signals provided to the user are shown in the chart below:

Trigger In	Inputs initiate an exposure or sequence
Trigger Ready Out	Status indicating if the camera can accept another trigger
Read Out	Status indicating the camera is currently digitizing
Expose Out 1	Output for controlling illumination source 1
Expose Out 2	Output for controlling illumination source 2
Expose Out 3	Output for controlling illumination source 3
Expose Out 4	Output for controlling illumination source 4

Special BNC breakout cables are provided to easily access these signals. Each breakout BNC cable is labeled according to its function. One BNC output is a spare for future use.

Trigger Modes

The Kinetix22 camera supports an internal trigger mode, several hardware trigger modes, and two software trigger modes. Each of these is described below, beginning with the internal and hardware trigger modes.

Internal Mode

Internal Mode is the default triggering mode for the Kinetix22 camera. The start of a sequence of acquisitions is initiated by the software/application. Once initiated, each frame captured in the sequence is controlled by the internal timing generators of the camera. Camera settings, expose out behavior, and sequence size are set in the software application prior to acquiring the sequence. Internal Mode is used when synchronization with other devices is either not required or is controlled independently through the software.

Trigger-First Mode

Trigger-First Mode is similar to Internal Mode but requires a hardware trigger from the I/O connector. Hardware triggers enable a higher precision of acquisition timing than software triggers. The rising edge of an external trigger initiates the start of a sequence of acquisitions. Once initiated, each frame capture in the sequence is controlled by the internal timing generators of the camera. Camera settings, expose out behavior, and sequence size are set in the software application prior to acquiring the sequence.

Edge Mode

Like Trigger-First Mode, Edge Mode requires a hardware trigger but 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 behavior, and sequence size are set in the software application prior to acquiring the sequence.

Level Trigger Mode

Level Trigger Mode uses the duration of the trigger-in high signal (+5 V) to define the exposure time. This offers flexibility to control the exposure time for each frame. In Level Trigger Mode, the beginning of the next frame cannot happen until all the rows have read out so that the frame-to-frame time is the sum of the trigger high duration plus the product of the number of rows x the line time.

Level Trigger Overlap Mode

Level Trigger Overlap Mode behaves somewhat like Level Trigger Mode, as the camera integration time is specified by the duration that the trigger-in voltage is high. Unlike Level Trigger Mode, however, Level Trigger Overlap Mode allows concurrent exposure and readout of the sensor consistent with rolling shutter behavior. If triggered by a second input trigger, Row 1 of Frame 2 in a series can begin exposing while Row N of Frame 1 is still reading out. In this way, the time delay between exposures can be minimized.

Usage Summary of Level Trigger Modes

In Level Trigger Mode, the trigger voltage can fall to 0 before all the rows in Frame 1 have received the full exposure time that Row 1 received. In this case, the rest of the rows in Frame 1 will be exposed for a time equal to Row 1's exposure time, and then all rows in Frame 1 are read out. This preserves the signal across the field of the sensor but delays the time before Frame 2 can be triggered.

Level Trigger Overlap Mode minimizes dead time between exposures but the individual rows in the image might not receive the same integration times. As an example, in a 10 row image, with a 1 msec time to read a row, the trigger-in signal is set high for 6 msec. Row 1 integrates signal for 6 msec and reads out. Row 2, which started 1 msec after Row 1, integrates for 5 msec and then reads out. Rows 7-10, having started after the trigger-in has dropped to 0, integrate for 0 msec and then read out. This implementation maintains the full dimensions of the image but carries the risk that poorly set timing inputs can lead to the image having different exposure times down the columns.

Note: The Kinetix22 camera's software trigger modes are essentially identical to the hardware trigger modes except for the trigger input. In software trigger modes, the trigger input will be provided by the application itself in the form of a host command. Usually, the application will use a periodic timer to issue the software trigger, or it will issue the software trigger based on another software event (e.g., a click of a button, a serial port signal from another device). The latency between issuing a PVCAM software trigger command and actual acquisition start should be less than a millisecond. For more details, refer to the *PVCAM User Manual* and SDK documentation.

Software Trigger Edge

This mode is an alternative to the Edge Mode described above. Every new acquisition has to be started by an independent trigger signal sent by the host as a PVCAM command.

Software Trigger-First

In this mode, which is an alternative to the hardware Trigger-First Mode, the sequence or continuous acquisition is started by a single software trigger sent by the host as a PVCAM command.
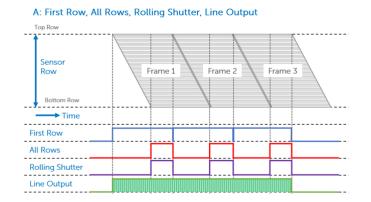
Expose Out Modes

User-settable Expose Out Modes provide flexibility in different experimental scenarios.

The Expose Out trigger modes for Kinetix22 include:

- First Row
- All Rows
- Rolling Shutter
- Line Output
- Any Row

The actions of these modes are illustrated in the next two figures (A, B). Suggested uses, subtle differences between similar modes, and additional details are described in the following text.

A: First Row, All Rows, Rolling Shutter, Line Output

First Row Mode

The trigger signal from the camera is high only when the first row of a frame is being exposed. The length of the signal is equal to the exposure time for the first row. Exposure time is equal to the time that is set in the software application. In the figure above, the voltage only falls to zero during the readout of the first row. First Row Mode can be used as a voltage time stamp for time-lapse imaging, or to initiate some other action connected to the beginning of the capture of an image frame.

All Rows Mode

The trigger voltage is high only when all the rows on the sensor, or in a region of interest (ROI), are actively exposing. This mode and Rolling Shutter Mode are useful for controlling external light sources in a way such that the signal detected at the camera starts and finishes at the same time across all rows. This provides a Pseudo-Global Shutter imaging method, where all rows of the sensor detect signal using the same start and stop times.

The duration of the Expose Out signal is equal to the time between the start of the last row's exposure and the end of the first row's exposure. In All Rows Mode, the timing of sequential exposures is altered so that the exposure time set in the software application is maintained. Each row exposes for the length of time as defined by the software application plus the time required for each row to start exposing.

Rolling Shutter Mode

As with All Rows Mode, the trigger voltage is high in Rolling Shutter Mode only when all the rows on the sensor, or in an ROI, are actively exposing. In contrast to All Rows Mode, the goal of Rolling Shutter Mode is to maintain a set frame rate, which is dependent on the readout rate. The duration of a frame is equal to the readout time necessary for the number of rows plus the exposure time. If the frame rate and exposure time input into software are not greater than the total readout time of the sensor, then the output trigger
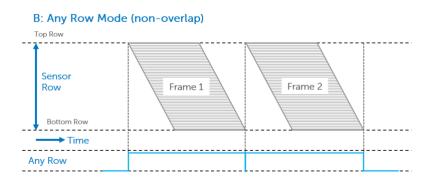
voltage will never go high. As with All Rows Mode, Rolling Shutter Mode is designed to provide Pseudo-Global Shutter behavior from the camera and light source.

Line Output Mode

The Line Output Mode is used for synchronization purposes when using Programmable Scan Mode. Line Output Mode creates a rising edge for each row that the rolling shutter readout mechanism of the sensor advances.

Any Row Mode

Any Row Mode stands apart from the other trigger modes in that it forces the camera out of "overlap" operation (i.e., the ability to expose one frame while still exposing and reading the previous frame). This is clearly illustrated below, where Any Row Mode has distinct gaps between the frames. These gaps are not found in the other trigger modes. The Expose Out I/O signal leaving the camera is high when any row in a single frame is exposing. The length of the Expose Out signal is equal to the time between the start of the first row's exposure and the end of the last row's exposure. Each line exposes for the same amount of time, which is equal to the time set in the software application. Maximum camera frame rates are not achievable in Any Row Mode but using this mode does avoid frame overlap.

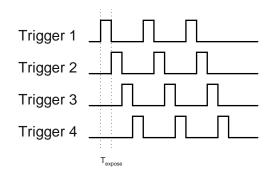B: Any Row Mode (non-overlap)

Multiple Output Triggers

The Kinetix22 camera has four independent trigger output signals. This enables hardware control over light sources that cycle through different excitation wavelengths during a sequence acquisition. For example, a multi-wavelength LED light source can rapidly switch between two different fluorochromes.

The enabled outputs are simply cycled with each frame in a sequence. For example, if two outputs are enabled, the output trigger signal is routed to output 1, output 2, output 1, output 2, and so on.

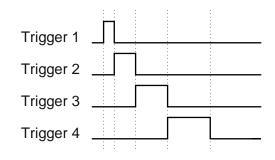If all four outputs are enabled, the sequence would be as follows:

SMART Streaming

Sequenced Multiple Acquisition Real Time Streaming, or SMART Streaming, is an exclusive Teledyne Photometrics camera feature that enables Kinetix22 to capture a continuous sequence of images while cycling through a maximum of 16 pre-programmed exposure time values. This avoids the overhead of host communication time, resulting in very high frame rate imaging while maintaining the correct exposure level for each fluorophore.

The maximum exposure time per frame is 10 seconds, in keeping with SMART Streaming's high frame rate benefits.

By combining Multiple Output Triggers with SMART Streaming, it is possible to control the exposure time of each output independently. This is much faster than using software-based methods to control the timing of illumination devices.

Fan Speed Control

Fans are often used to remove heat from the camera due to their convenience. However, under demanding conditions, such as when the camera is used with an atomic force microscope, fan vibration isolation is insufficient.

Kinetix22 solves this problem in two ways. First, a new, innovative fan mounting system was developed that isolates fan vibration from the rest of the camera. Side-by-side testing with competing products indicated that Kinetix22 outperforms alternatives in terms of vibration isolation.

Secondly, the fan has variable speed control. The lower the fan speed, the lower the vibration transferred. Kinetix22 provides three fan speeds.

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To achieve the ultimate in low-vibration performance, the fan can be completely turned off in software. Kinetix22 provides liquid cooling ports for this purpose. Fan speed settings include:

1. High

2. Medium

3. Low

4. Off (i.e., liquid cooling)

Note: If the camera is inadvertently left on with the air and liquid cooling both disabled, a protection circuit will trip to prevent the camera from overheating. This circuit disables current to the sensor cooling system until the camera returns to the default temperature range. In this case, the camera is unable to cool the sensor. When setting the Kinetix22 camera on a flat surface, be careful not to block the air vents.

Note: The camera has been designed to operate at 0°C. Should you need to change the temperature setpoint, contact Teledyne Photometrics Customer Service.

Time Stamps

The Kinetix22 camera system is able to output "metadata" that describes data associated with each frame. Metadata contains useful information like the exposure time, ROI location, and time stamps. Metadata is inserted directly into the frame buffer and transferred together with the image data.

Time stamps are particularly useful. Kinetix22 generates Driver Generated Time Stamps (for legacy support) in the host PC. Hardware Time Stamps are generated in the camera. The accuracy of the Kinetix22 system's Hardware Time Stamps is approximately one line read time, so between 0.8 μsec and 80 μsec depending on the mode in use. This is far better than the 1 msec accuracy of Driver Generated Time Stamps. Hardware Time Stamps are given in units of 1 psec.

To display Hardware Time Stamps in the Micro-Manager application, metadata must be enabled for the Kinetix22 camera in the Device Property Browser. When acquiring a sequence, Hardware Time Stamps will be displayed in the metadata tab with the prefix "FMD" ("frame metadata").

Note: Kinetix22 has time stamps for "Bof" ("Beginning of frame") and "Eof" ("End of frame") events, which differ by the preset exposure time of approximately 10 msec. Hardware Time Stamps are given in units of 1 psec.
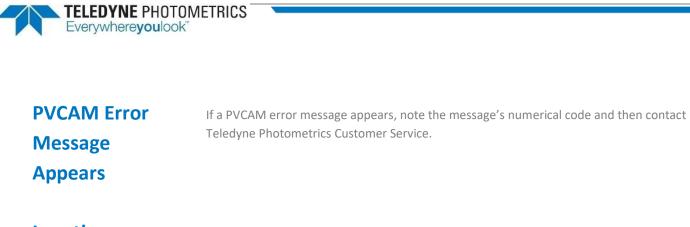
Next Frame	10
PVCAM-FMD-ExposureTimeNs	9993600
PVCAM-FMD-FrameNr	11
PVCAM-FMD-TimestampBofNs	254157974400
PVCAM-FMD-TimestampEofNs	254167804800

Chapter 5 – Troubleshooting

Note: For difficulty in troubleshooting, or if the symptoms are not listed here, contact Teledyne Photometrics Customer Service.

Difficulty Installing PCIe Cables

Kinetix22 cameras are remarkably trouble free given their high performance. Two common issues may arise at installation that can easily be confirmed and addressed.

A) The PCIe cables connect to the computer and the camera with a latch mechanism and should not slide out easily. Sometimes the supporting elements of the computer card slots can interfere with the cable insertion. In this case, the cable will not lock in place.

   To address this issue, reposition the PCIe card in the computer support or try a different PCIe slot. The cable should click into place and only be easily removable by pulling on the green release tabs on the cable connector.

B) Each Kinetix22 comes with two identical PCIe cables and it is important that an individual cable be connected to the same port number on the camera as on the PCIe board. Cross-connecting, such as when a cable connects port 1 on the camera to port 2 on the computer, can lead to data corruption and reduced performance.

   This issue is easily addressed during camera installation by adding a marker of some sort, like electrical tape, to each end of one cable and then confirming that port 1 on the camera is connected to port 1 on the PCIe card, with port 2 on the camera connected to port 2 on the PCIe card.

If you need further assistance, contact Teledyne Photometrics Customer Service.

System Does Not Boot Normally

If the operating system does not boot normally after the interface card is installed, try reseating the PCIe card. If this is unsuccessful, try installing the new card in another open PCIe 8x or higher slot. If this does not work:

1. Turn off the computer and remove the newly installed interface card.
2. Turn the computer on. If the system boots normally, there is probably an interrupt conflict between a previously installed device.

If you need assistance resolving the interrupt conflict, contact Teledyne Photometrics Customer Service.

New Hardware Found Dialog Box Does Not Appear

If the New Hardware Found dialog box does not appear after installing a new interface card:

1. Make sure the new interface card is inserted in an expansion slot according to the computer manufacturer's instructions.
2. Ensure the Kinetix22 camera is connected and powered on at least 30 seconds before starting the computer when using the PCIe interface.
3. When using the USB 3.2 interface, wait for the LED on the back of the camera to stop blinking before checking for "New Hardware Found" and the application.

It is possible that due to the power states settings of your computer, the PCI Express card was not properly detected. Follow this boot up procedure to see if the camera is detected when using the PCI Express interface:

1. Turn on the camera.
2. Wait for the LED to stop blinking.
3. Turn on the computer.
4. When the computer has booted, power cycle the camera.
5. When the LED stops blinking, restart the computer.

If the New Hardware Found dialog box still does not appear, contact Teledyne Photometrics Customer Service.

Images Not Displayed

If no images appear:

1. Confirm the camera switch is set to on.
2. Confirm that the Kinetix22 camera is selected in the imaging software application.
3. Power off the camera and the host computer and check all system connections (particularly the PCIe and power cables), then restart.
4. Confirm the camera is operational by taking an image with a lens attached to the camera. Using normal room lighting, place the camera on a table about three meters away from an object and acquire an image.

If the problem persists, contact Teledyne Photometrics Customer Service.

Camera Running Too Warm

It is normal for the camera to be slightly warm to the touch while in operation. However, if it is more than slightly warm to the touch (and at least one inch of space has been left around the camera for airflow), switch off the camera immediately and contact Teledyne Photometrics Customer Service.

PVCAM Error Message Appears

If a PVCAM error message appears, note the message's numerical code and then contact Teledyne Photometrics Customer Service.

Lengthy Pauses During Imaging

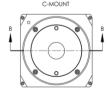If you notice lengthy pauses marked by a lot of disk activity while imaging:

- Close any other programs that may be running.
- Install more physical memory (RAM) in your computer system.

Kinetix22 Dimensional Drawings

105   21.41

I/O   LIQUID COOLANT IN

LED INDICATOR

USB 3.2 GEN2 10 Gbps

POWER SWITCH

POWER

PCIe

LIQUID COOLANT OUT

AIRFLOW OUT

AIRFLOW IN

8X 1/4-20 UNC ⤓ 6.35

26.1 — 54 — 3.75

106.2

106.2

Distances from Sensor to C-Mount for Kinetix22

C-MOUNT

B   B

17.84 (C-MOUNT FLANGE)
15.84 (LENS MOUNT ALIGNMENT PLATE)
12.05 (CAMERA FRONT PLATE)
9.05 (EXTERNAL WINDOW SURFACE)
0 (SENSOR PLANE)

SECTION B-B

All measurements given in millimeters.

Camera Weight

4 lbs.
(1.8 kg)

Sensor Specifications

Window	UV-grade fused silica
	Broadband MgF$_2$ anti-reflective coating on both surfaces

BSI Scientific CMOS Sensor Array	
Sensor Type	Teledyne Photometrics Kinetix22 sensor
Sensor Process	Backside-illuminated scientific CMOS
Resolution	2400 x 2400 pixel array
Pixel Size	6.5 µm x 6.5 µm

Power Supply Specifications

Voltage Input:	100-240 V~ @ 50-60 Hz
Current Input:	2.5 A (110 V nominal)
Voltage Output:	+12 V @ 10 A
Maximum Power Output:	140 W
Power Supply Weight:	1.80 lbs. (0.82 kg)
Supply Cable Length:	4 ft. (1.22 m)
Certifications:	CE, UL, CUL, FCC, PSE
	Efficiency level VI

Note: CE certification applies to the Kinetix22 camera only when the camera system operates with a CE-approved power supply.
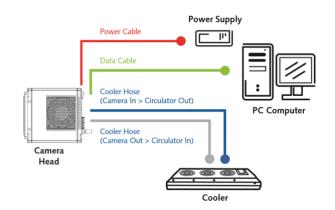
Appendix A – Liquid Cooling Setup Instructions

Warning: Use of equipment not originally provided by Teledyne Photometrics for use with liquid cooled cameras will void any and all warranty coverage of the product.

1. Unpack the cooler and hose assembly.
2. Confirm the cooler and hoses are pre-filled with blue-colored coolant.
3. Press one hose connector into its mate on the cooler.
4. Repeat with the second hose connector.
5. Press each hose connector onto its mating connector on the camera:
   - Circulator Out > Camera In
   - Camera Out > Circulator In
   - Listen for the "click."
6. Pull each connector to ensure they are locked.
7. Inspect the setup to ensure the hose connectors are secure at the cooler and camera.
8. Set both the pump speed and fan speed to level 10 on the front display on the circulator.
9. Plug in the cooler and turn it on.
10. Look through the clear cover on the coolant reservoir to observe the liquid level and confirm circulation. (The liquid surface will appear agitated with normal circulation.)
11. Turn on the camera power and continue the setup per the *QuickStart Guide.*
12. Use software to set the camera fan speed to "off." **DO NOT turn off camera fan without liquid circulating.**

Please note there is no temperature adjustment on the unit.

Appendix B – Hotswap/Hotplug Capability

Note: Teledyne Photometrics cameras using PCIe once required the camera to be turned on and initialized before starting the computer. This is not necessary for the Kinetix22 camera. The Kinetix22 can now be turned on after the computer, and the camera can be power cycled without the need to restart the computer.

Requirements:

- Kinetix22 camera with firmware 30.29.03 or higher. The camera firmware can be confirmed in PVcamTest software, which is installed along with PVCAM.
- PVCAM 3.9.8.0 installed on the computer.
- Dolphin PCIe Card with Firmware 8.12. This is the firmware on cameras shipped after June 15, 2021.
- This capability has been tested using the Teledyne Photometrics-recommended computer systems listed here, the Dell Precision Tower 5820, and the HP Z4G4 system, commonly supplied by Nikon, Olympus, and Zeiss. Contact Teledyne Photometrics Customer Service if you find this capability does not work with your computer system.

To start the camera after the computer boots up:

1. Ensure the computer and camera are both powered off.
2. Ensure the camera is connected to the computer with appropriate PCIe cables.
3. Boot the computer and let it complete its startup.
4. Turn on the camera. Then wait for the green blinking lights on the PCIe card to become steady green and for the yellow light on the back of the camera to turn off (approximately 15 seconds).

Note: If the user attempts to initiate software to control the camera before the camera initiation is finished (i.e., blinking lights off), the camera will not function even though it is recognized in device manager.

5. Enable the software and use the camera.

To gain access to the camera after camera shutdown without rebooting the computer:

1. Shut down all software to which the camera may have been connected.
2. Power down the camera and wait 5 seconds.
3. Turn on the camera. Then wait for the green blinking lights on the PCIe card to become steady green and for the yellow blinking light on the back of the camera to turn off (approximately 15 seconds).
4. Start up the imaging control software and confirm it is working with the camera.

If these steps do not resolve the issue, you may need to power cycle the computer and camera. Should this action not restore functionality, please contact Teledyne Photometrics Customer Service.

Appendix C – Multi-Camera Configuration

Using multiple Kinetix22 cameras with a single PCIe card:

The Dolphin PXH832 PCI-Express card specified for use with Kinetix22 has multiple ports and can be configured for either PCI-Express 4 Lane, 8 Lane, or 16 Lane operation. By employing these ports for multiple cameras, the user has the opportunity to run up to 4 cameras (in some modes) via the same card without experiencing a reduction in frame rate.

The maximum data rates (in frames per second) achievable for various camera number and mode combinations are presented in the following table. The combinations for which the maximum published frame rate for a given mode can be achieved have been highlighted in green.

Note: Teledyne Photometrics highly recommends using a 16x PCIe card slot on the motherboard for multi-camera setups in order to achieve maximal data throughput.

			Max Frame Rate per Camera		
Mode	No. of Cameras	MB/sec	PCIe x4	PCIe x8	PCIe x16
Dynamic Range	2	3242	83	83	83
	3	4863	67	83	83
	4	6484	41	83	83
Sensitivity	2	2637	89	89	89
	3	3955	89	89	89
	4	5273	67	89	89
Speed	2	9766	202	403	498
Sub-Electron	2	213	5.2	5.2	5.2
	3	319	5.2	5.2	5.2
	4	426	5.2	5.2	5.2

On delivery, the PCIe card is set to x8 mode, allowing control of 1 or 2 cameras <u>in all operating modes,</u> with DIP switches in the configuration below.

This allows operation of up to 2 cameras from the same board with x8 performance.

To configure the card for 3 or 4 cameras, it is necessary to change the DIP switches on the card to the configuration below, which treats each connection as a single x4 port.

More information on card settings can be found in the Dolphin PCI Express PXH832 adapter manual available online:
https://www.dolphinics.com/download/PX/OPEN_DOC/PXH832_users_guide.pdf

Using long optical cables with Kinetix22:

The PXH832 card that comes with Kinetix22 is compatible with active fiberoptic PCIe cables measuring up to 100 meters in length. No special configuration of the card needs to be performed for working with these cables. Maximum achievable frame rates (in frames per second) using the fiberoptic cables are presented below. CWAKE and CPOWERON are not supported using standard AOC cables.

	1x PCI-E 16 Lane (default shipping configuration)		2x PCI-E 8 Lane (Configuration to run 2 cameras on 1 PCI-e Card. Tested with single camera)	
	100m	50m	100m	50m
HDR - 16-bit	83	83	83	83
Sensitivity - 12-bit	88	88	88	88
Speed – 8-bit	458	498	287	442

Note: Only PCIe fiberoptic cables from Dolphin are supported. Standard MiniSAS-HD AOC cables are not supported.

Notes