TELEDYNE PHOTOMETRICS
Everywhereyoulook™

IRIS

Iris User Manual

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- 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.

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CERTIFICATE OF CONFORMITY

This certificate is to recognize

Holder: PHOTOMETRICS

Address: 3440 E. Britannia Drive, Suite 100,
Tucson, AZ 85706

Product: Iris 9 Camera

Identification: Iris Camera

Standards: FCC Part 15, Subpart B
ICES-003 Issue 6
EN 61326-1:2013
CISPR 11:2009/A1:2010
EN 61000-3-2:2014
EN 61000-3-3:2013

Summary: QAI Laboratories confirms that the product tested as outlined in report E10585-1801 Rev 0.0 complies with the standards listed above. This certificate does not imply assessment of the production of the product and does not permit the use of a QAI mark of conformity. Photometrics declares that the product tested represents the equivalent or worst case equipment under test and that any testing performed by QAI Laboratories applies equally as well to models:

Rajinder S. Atwal, Engineering Manager-
EMC Department

Parminder Singh, Director-
EMC Department

Certificate # E10585-1703_Photometrics_Rev1.0

Issued Date: May 09, 2018
Expiration Date: N/A

Table of Contents

Chapter 1 - Overview

About This Manual

This Iris Scientific CMOS Camera User Manual is divided into five chapters. Teledyne Photometrics recommends you read this entire manual before operating the camera to ensure proper use. The chapter contents are briefly described below.

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

- **System Installation** — Instructions for connecting the Iris Scientific CMOS camera to a computer via the PCI Express interface card or the USB3.0 bus.
- **Theory of Operation** — A basic overview of Scientific CMOS camera technology as used in the Iris Scientific CMOS camera.
- **Operating Features** — Iris features and how to optimize them for speed and sensitivity, and how to use the different trigger modes.
- **Troubleshooting** — Answers to common camera system questions.
- **Basic Specifications** — Specifications for Iris 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.
- Never open the camera. There are no user-serviceable parts inside the Iris Scientific CMOS 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-Iris cables, PCI Express interface cards or power supplies may result in permanent damage to the system.

Environmental Requirements

The Iris Scientific CMOS 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 Iris Scientific CMOS camera system in its original packaging. To protect the system from excessive heat, cold and moisture, store at an ambient temperature between 0°C and 40°C with a relative humidity of 0% to 90%, noncondensing.

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 Iris 9, or a standard F-mount adapter for the Iris 15. The camera also allows you to install any lens that is compatible with a either of these threaded video mounts if its optics do not extend behind the flange of the lens. Iris can be mounted to optical tables, tripods or custom stands using the four ¼-20 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 Iris Scientific 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 Iris Scientific 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. Again, use only a Iris Scientific CMOS PCI Express data cable and Iris PCI Express interface card with the camera. Using a different cable or interface card may result in permanent damage to the system.

Introduction

The Iris Scientific CMOS camera system includes the following hardware components:

- Iris Scientific CMOS Camera
- PCI Express (PCIe) interface card (For PCIe cameras only)
- PCI Express data cable (For PCIe cameras only)
- USB 3.0 SuperSpeed A to B data cable (For USB cameras only)
- A 12V/ 5A power supply with international power cord set
- Two single-line MMCX trigger cables
- USB memory device containing PVCAM library and drivers
- Quick Installation Guide

Iris system components are linked by the PCI Express or USB3.0 data cable and controlled by the host computer system. 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.

Getting to Know Iris

Highlights of the Iris Scientific CMOS camera:

- USB3.0: Data Connection
- DATA: High Speed PCI-Express Connection
- Initializing: LED blinking indicates the camera is initializing
- Trigger: Single-line MMCX trigger cables
- DC IN: Connection to external 12V 5A DC power supply

The Iris camera package includes the PVCAM camera control software library and drivers needed to use the camera with a variety of third party imaging software. To obtain the latest version of the library and drivers visit the Teledyne Photometrics website. The Teledyne Photometrics website also contains listings of third party software applications that support the Iris.

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 Iris.

Host Computer Requirements

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

- Windows 8/10 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
- USB3.0 port for use with the Iris USB3.0 interface
- An open PCI-Express 4x (4 lane) interface slot or higher for use with the Iris PCIe 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 PCI Express Interface Card

Because of the data rate resulting from 32fps 5056 x 2960 imaging with a 16-bit output, the data rate of the Iris camera is significantly higher than previous generations of scientific cameras. At 958 MB/s, Iris requires a more powerful computer interface than previous generations of cameras to obtain the maximum frame rate. For this reason, Iris is supplied with a high speed PCI Express bridge card that is capable of sustaining the bandwidth requirements of the camera.

TIP: PCI Express is a high speed peripheral data bus used by the computer to communicate with video cards, high speed Solid State Drives, and image frame grabbers. The PCI Express interface card is simply an adapter between the computer's internal PCIe bus and the camera.

While this has benefits in cost, reliability, simplicity, and performance, it is important that the camera is powered on for 30 seconds before starting the PC. This will ensure that as the computer goes through the boot process, it discovers the camera on the PCIe bus.

Install the High Speed PCI Express Interface

Figure 2

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

Warning: Do not use the PCIe interface supplied with the QImaging optiMOS Scientific CMOS camera with the Teledyne Photometrics Iris Scientific CMOS camera. While they have a common cable and connector, they are not compatible.

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

Figure 3

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

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

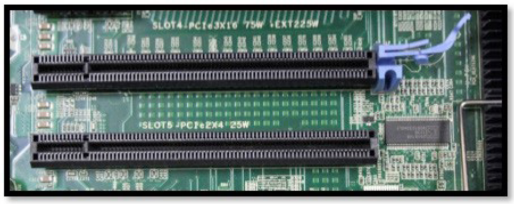


Figure 4

5. Holding the Iris PCIe 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 Iris to the PCIe Bus

The Iris Scientific CMOS camera data cable is a quick insertion, quick release cable that works with the interface card and camera. Either end of the cable can be plugged into either device, and in any order.

Figure 5

The connector can only be inserted with the correct orientation, do not force the connector. If the connector does not insert, simply turn the connector over and retry.

Hint: With the camera oriented so the labels on the camera are upright, the green "quick release" pull tab on the cable will be facing down.

Connect the PCIe interface cable to both the camera and PC.
Connect the power supply to the Power connector on the rear of the camera.
Plug the power cord into the power supply and then into a suitable wall outlet. There is no power switch on the Iris, plugging the power supply into a live outlet will power the camera. LED will be blinking after power on.
Start up steps for Iris PCIe camera:
.

1. Power on camera
2. LED blinks while camera calibration is loading in the background
3. Power on host PC computer
4. LED off — background loading completed
5. Camera is initialized and ready to communicate

Tip: The power supply and connector used by the Iris Scientific CMOS camera is 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 the Iris.

Connecting Iris with USB 3.0

Iris's USB3.0 interface is ubiquitous and easy to use. To use the interface, the PC must have an open USB3.0 port. Iris is not USB2.0 compatible. USB3.0 ports are usually indicated by the SuperSpeed+ logo and are typically blue in color.

Tip: USB devices sharing the same bus as Iris contend for available bandwidth, potentially causing the camera to drop frame rate. For this reason, Teledyne Photometrics recommends isolating the camera to its own USB3.0 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 USB3.0 interface card for use with the camera. In this case Teledyne Photometrics recommends using the PCIe interface described above, as it also provides improvements in maximum frame rate.

It is not recommended to connect to Iris external USB3.0 hubs.

Note that the ends of the USB3.0 cable are different between the camera and PC, and require a specific orientation. The camera has a "Micro-B" connector and the computer will have a "Type A" connector. Do not force insertion when connecting the cable – if significant resistance is encountered stop, reexamine the connection, and if correct, retry.

With the USB 3.0 cable connected on both the camera and PC you are now ready

Figure 6

Connect the power supply to the Power connector on the rear of the camera. There is no power switch on the Iris, plugging the power supply into a live outlet will power the camera.

Plug the power cord into the power supply and then into a suitable wall outlet. LED will be blinking after power on.
Start up steps for Iris PCIe camera:

1. Power on host PC computer
2. LED on backplate blinks while camera calibration is loading in the background
3. Power on host PC computer
4. LED on backplate off — background loading completed
5. Camera is initialized and ready to communicate

Chapter 3 – Theory of Operation

Introduction

Scientific CMOS sensors are quickly becoming the dominant sensor type in imaging technology. CMOS sensors are able to provide the highest levels of sensitivity due to the improved Quantum Efficiency (QE) compared to CCD sensors. This QE coupled with high frame rates, high pixel counts, and low electronic noise provide the most complete low-light scientific imaging solution.

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 11-bit or 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 to be digitized.

On a CMOS device – the entire 2048 voltage conversions needed to digitize a row happen in parallel. The sensor in the Iris Scientific 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 the Iris's nine (or fifteen) 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 Iris'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 section, the column ADCs present in Scientific CMOS devices have limited dynamic range. This 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 ~14,000 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 cameras FPGA. **The result is a single 1x gain of approximately 0.22e/ADU.**

In practice, Iris's advanced FPGA based signal processing does an excellent job of gain combining as evidenced by the quality of gamma transfer functions (linearity) and photon transfer functions (signal versus noise). With careful observation and uniform illumination of the sensor, the zone where two measurements overlap can be seen as a slight static vertical pattern in the image. This is inherent on all current Scientific CMOS generation Scientific CMOS cameras. While impacting image quality, these cannot be addressed without negatively impacting image photometry and wait for further improvements to the on-sensor ADC conversion.

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 pixels 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 reading one row, while exposing all of the other rows (The row being digitized “rolls” through the sensor).

For Iris, the time to digitize a single row is 10.26μsec for PCIe and 20.42μsec for USB 3.0 and consequently the delay between the start of exposure between two adjacent rows is approximately 10.26μs (or 20.42μs). Digitizing 2960 rows of pixels, the time delay from the top to the middle of the sensor is approximately 30.4 ms. Since readout and exposure are overlapped, the sensor achieves the maximum frame rate of 32fps with PCIe interface (Iris 9 and Iris 15) and 16fps for Iris 9 USB/ 10.5fps for Iris 15 USB).

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

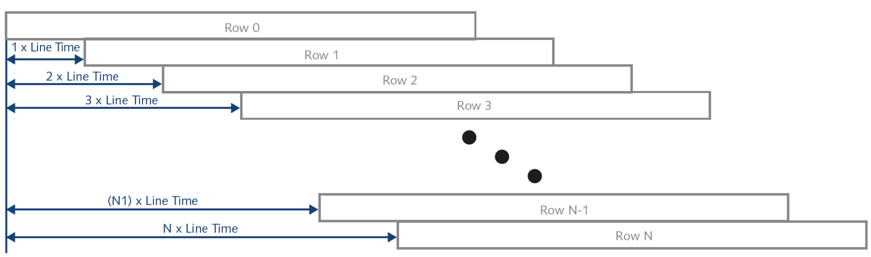


Figure 7: Rolling Shutter Exposure Row by Row Exposure Start/End Offset

The downside of Rolling Shutter readout is that changes in the scene on similar time scales is distorted, as each row samples the image at different times. This is the well-known “rubber band” effect – but 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 (lasers, LEDs) achieves a pseudo global shutter effect. This triggering mode is described in the device synchronization section of this manual.

Digital Binning

Highlights of the Iris Scientific CMOS camera are shown below: 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.

Iris 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.

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 and 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, or using additional circuitry that performs a global reset of all pixel photosites.

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

Scientific cameras produce a fixed artificial signal offset known as bias offset. This offset is present even when no light is falling on the sensor and the exposure time is set to zero. This preserves quantitation even down to signals of a few electrons per pixel. Typically, the user subtracts this offset before performing quantitative analysis post-acquisition.

The recommended protocol is to capture a new series of bias frames at the start of each experimental run. The series of frames can be averaged to remove noise, then used to remove the bias offset during subsequent image analysis. This can also be used to monitor for light leaks and other systematic effects that can impact experimental results.

Pixel Noise Filters

Note: The Iris Scientific 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. Iris 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 x 100.

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:

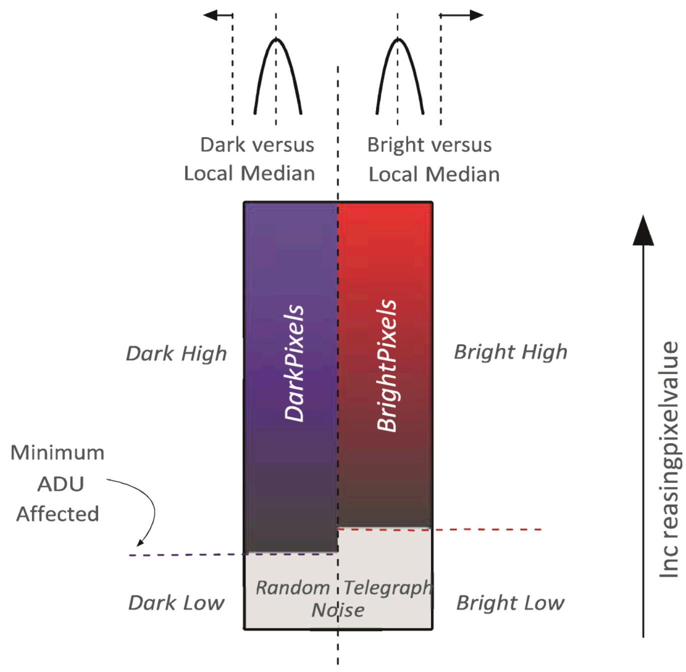


Figure 8: Pixel Noise Filter

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.

Signal Processing

The Iris has additional special capabilities that go well beyond the sensor. It is designed with high-speed DDR3 memory and high speed FPGA’s (Field Programmable Gate Arrays) in order to provide new opportunities for extracting the best information from acquired images.
Teledyne Photometrics has leveraged the revolution in computational imaging with many new capabilities. The Iris making computational imaging technology easy to deploy and accessible by embedding computational power inside the camera.

Chapter 4 – Operating Features

Introduction

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

Operating Frequencies

Iris has a single pixel rate or speed: 480 Mpixels per second. System performance is optimized for this data rate, delivering the highest frame rates while maintaining the lowest noise, which delivers the best imaging quality. The need to change readout rates is eliminated.

Gain States

Iris has a single, 16-bit combined gain value. The need for providing multiple gain choices is largely eliminated through the use of the gain combiner.

Bias Offset Setting

The factory default bias level is approximately ~300 DN. If supported by the software application being used, the bias level can be changed. It is recommended that this value not be changed as the preset values for the defective pixel noise filters are set with this value.

Clearing Mode Selection

In normal video-rate imaging, Iris's clearing mode should be set to "Clear Pre-Sequence". In "Clear Pre-Sequence", one sensor clear occurs prior to acquiring an image sequence, but no extra clearing is done between frames. This eliminates unnecessary sensor clearing and maximizes frame rates.
If a CMOS sensor has an electronic global clearing function, "Clear Pre Sequence" also ensures there is no sensor clearing while readout is taking place, otherwise a portion of the image would be removed before it could be digitized.
The following waveforms show how the overlap behavior of "Clear Pre-Sequence" functions for the Iris camera.

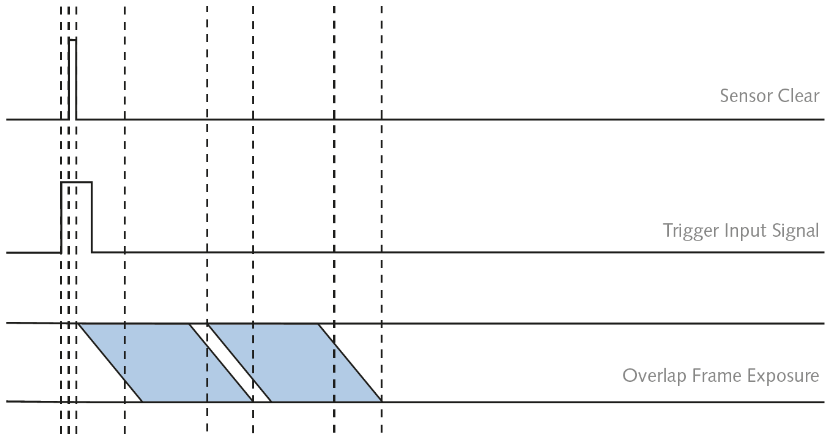


Figure 11

Tip: In some software applications, multiple clearing modes may be listed as they are required for other cameras, but when using Iris, be sure to only use “Clear Pre-Sequence”.

For time-lapse acquisitions with a significant delay between frames, clearing before each exposure may be necessary to clear accumulated dark current. If the time lapse is acquired under computer timing control, individual snaps taken with “Clear Pre-Sequence” turned on will be cleared with each new acquisition.

If the time-lapse is acquired using timing generated by the camera or an external timing generator, “Clear Pre-Sequence” will clear the sensor only for the first frame. In this case, “Clear Pre-Exposure” should be used as there is no concern over maximizing frame rate when each frame is separated by several seconds or more.

Regions Of Interest

Regions of Interest (ROIs) are image sub regions 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 rates increase with decreasing numbers of rows contained in the ROI. By reducing the number of rows, frame rates above 1000fps are achievable with small ROIs. As a result, the 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.

Note: Very small ROI’s of less than 2000 pixels can result in data transfer problems during high-speed DMA data transfers to host memory. If a small ROI does not return an image, try changing the ROI pixel area to make it larger than 2000 pixels, or chose a different starting pixel for the ROI.

Programmable Scan Mode

Note: Programable San Mode is only available on Iris PCIe cameras after firmware version 21.20.00 and using PVCAM 3.8.0.6 or higher

Programmable Scan Mode provides increased control over the rolling shutter exposure and read-out functionality of CMOS sensors. The rolling shutter read-out behavior is a common implementation on CMOS sensors, and Programmable Scan Mode provides access to the sensor timing settings to allow optimization around imaging requirements.

Programmable Scan Mode provides access to three modes:
- Auto

    When Programmable Scan Mode is set to Auto, the line-time is set to 1 line. This provides the highest framerates and minimal control over the ability to set the width between the reset and readout signals. There is no delay added after the line time. This is the default option for the Scan Mode.

- Line Delay

  When Programmable Scan Mode is set to Line Delay, a delay can be added after the line-time, slowing the propagation of the reset and readout signals. This causes the effective line time of the sensor to be increased. This delay is added onto the default line time in increments equal to the line-time.

  $$\text{Line Time}_{\text{Effective}} = \text{Line Time}_{\text{Sensor}} + (\text{Line Time}_{\text{Sensor}} \text{ x Line Delay Value})$$

A value of 1 adds a delay equal to 1 line-time. This results in an effective line-time equal to double the value of line time.

$\text{Line TimeSensor} = 10\mu s$

$\text{Line Delay Value} = 1$

$\text{Delay} = 10\mu s \text{ x } 1 = 10\mu s$

$\text{Line Time}_{\text{Effective}} = 10\mu s + 10\mu s = 20\mu s$

A value of 10 adds a delay of 10 line-times which results in an effective line-time equal to 11 times longer than the default line-time.

$\text{Line Time}_{\text{Sensor}} = 10\mu s$

$\text{Line Delay Value} = 10$

$\text{Delay} = 10\mu s \text{ x } 10 = 100\mu s$

$\text{Line Time}_{\text{Effective}} = 100\mu s + 10\mu s$

The frame rate when imaging in this mode is determined by the number of rows being imaged and the Effective Line Time.

$$\text{Readout Time}_{\text{Image}} = \text{Line Time}_{\text{Effective}} \text{ x } N_{\text{Rows}}$$

$$\text{Frame Rate} = \frac{1}{\text{Readout Time}_{\text{Image}}}$$

A Scan Width parameter is available and reports the number of rows between the reset and readout signals.

- Scan Width

  When Programmable Scan Mode is set to Scan Width, the number of rows between the reset and readout signal can be set. It gives direct control to set the size of the imaging region.

Scan Width = Number of Rows between Reset and Readout

When the Scan Width is set, the effective line time required is automatically calculated.

$$\text{Line Time}_{\text{Effective}} = \frac{\text{Exposure Time}}{\text{Scan Width}}$$

A Scan Line Time parameter is available and reports the Effective Line Time in nanoseconds Programmable Scan Mode also provides control over the direction of the scan. The available options are:

- 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 towards the bottommost row.

  Each subsequent frame acquisition restarts at the topmost row.

- Up

  A scan direction of Up inverts the direction of read out. The rolling shutter starts at the bottommost row and propagates upwards towards 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 alternates the direction of acquisition. The rolling shutter starts at the topmost row and propagates downwards towards the bottommost row. For the next frame, the rolling shutter will begin at the bottommost row and propagate upwards towards the topmost row.

  The acquisition will continue to alternate the readout direction between frames. The image orientation when acquired in this mode will have no inverted frames and will be consistent with the Down scan direction. Figure 4 shows how this parameter can be changed in Micro-Manager.

Device Synchronization (Triggering)

Iris offers several methods of integrating with external hardware devices. Each camera has four MMCX connectors on the back of the camera for trigger input/output operations. The signals provided to the user are:

Trigger In (TRIG IN)	Inputs initiate an exposure or sequence
Trigger Ready Out (TRIG RDY)	Status indicating if the camera can accept another trigger
Read Out (RD OUT)	Status indicating the camera is currently digitizing
Expose Out (EXP OUT)	Output for controlling illumination source 1

Single-line microminiature co-ax (MMCX) cables are included with the camera to access these functions. Each signal requires a cable that can be read with an oscilloscope or signal analyzer.

Trigger Modes

Mode (Internal)

Timed mode is the default triggering mode for Iris. 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 behavior 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.

Trigger-First Mode

Similar to Timed Mode but requires a hardware trigger from the I/O connector. Hardware triggers enable a higher precision of acquisition timing than software triggers. 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 is set in the software application prior to acquiring the sequence.

Edge Mode (Strobed 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 behavior and sequence size is set in the software application prior to acquiring the sequence.

Expose Out Behaviors

Any Row

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 what is set in the software application. Maximum camera frame rates are not possible in this mode but this does avoid frame overlap.

Although "First Row" behavior provides the maximum camera frame rates, it does not avoid the overlap due to rolling shutter. This mode is not recommended if trying to alternate between excitation wavelengths.

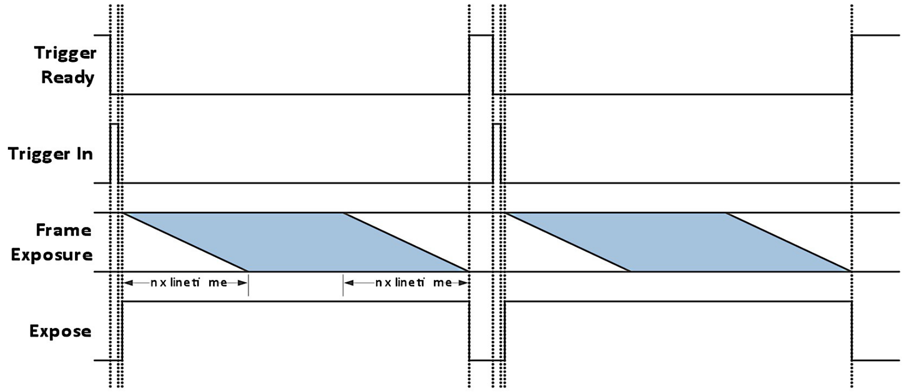


Figure 13

All Rows

The "Expose Out" I/O signal leaving the camera is high only when all rows within a single frame are exposing simultaneously. The length 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, which is also equal to the exposure time set in the software application. Each row exposes for the length of time as defined by the software application plus the time required for each row to start exposing (approximately 10ms).

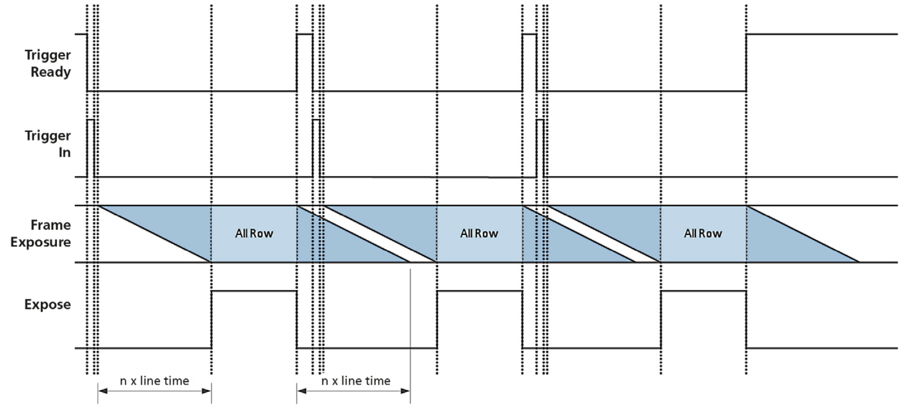


Figure 14

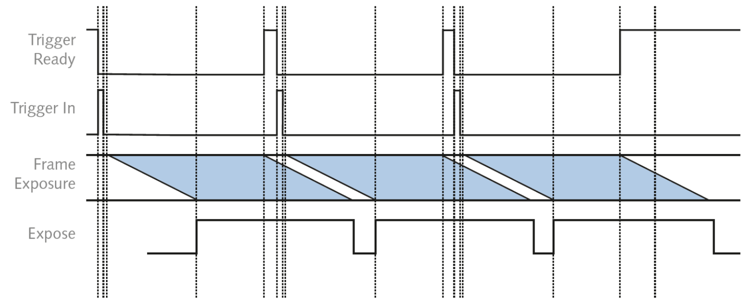
All Rows provides an effective global shutter with the speed and low noise benefits of rolling shutter, but eliminates rolling shutter motion artifacts. This mode is recommended for synchronizing the camera with high speed light sources that alternate excitation wavelengths for high speed multi-channel fluorescence. In this mode, user defined exposure time + 10ms defines camera frame rate.

The following conditions may be defined for each expose out behavior:

	First Row Expose	Any Row Expose	All Row Expose
Expose =< Frame Time	Yes	Yes	No
Expose > Frame Time	Yes	Yes	Yes
32fps (Full Frame)	Yes	No	Yes
Exposure Overlap	Yes	No	Yes
Simulated Global Shutter	No	No	Yes

Rolling Shutter

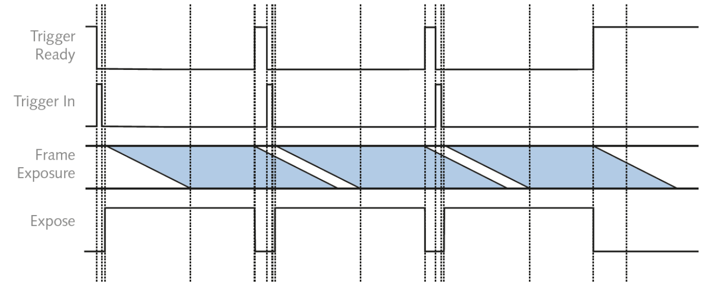
Rolling shutter mode takes all rows that have been taken simultaneously so as to capture an image at an instant. The expose out signal length is equal to the time between the start of the second row and the end of the first row's exposure, which is the shortest expose out time.



In the exposure and readout signal tracing would result in an expose out signal equal to the exposure time set in the application minus the frame readout. Each row is exposed for the exposure time minus the time required for each row to start exposing.

First Row

In this mode the "expose out" signal length is equal to the time between the start of the first row's exposure and the end of the first row's exposure. For both first row and all rows mode, the expose out signal will equal to the exposure time set in the API



Line Output Mode

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

SMART Streaming

Sequenced Multiple Acquisition Real Time Streaming, aka SMART Streaming, is an exclusive Teledyne Photometrics camera feature that enables Iris 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 the SMART Streaming high frame rate benefits.

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

Cooling

Iris solves the problem of sensor and electronics cooling 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 Iris outperforms alternatives in terms of vibration isolation.

With it's combined TEC and forced air cooling design, the Iris the fan speed, the lower the vibration transferred. Iris provides three fan speeds, and even on the lowest setting, it can still reach nominal 0° sensor cooling in a 23° ambient.

Advanced Features

The ideas behind two of Iris's unique signal processing capabilities are described in Chapter 3, Theory of Operation.

Chapter 5 – Troubleshooting

For difficulty in troubleshooting or if the symptoms are not listed here, 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 4x 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 to the computer and booting Windows 7:

1. Make sure the new interface card is inserted in an expansion slot according to the computer manufacturer's instructions
2. Ensure Iris is connected and powered on at least 10 seconds before starting the computer when using the PCIe interface.
3. When using the USB3.0 interface, wait for the LED on the rear of the camera to stop blinking before checking for "New Hardware Found" and opening the application.

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

1. Turn on Camera
2. Wait for LED to stop blinking
3. Turn on Computer
4. When computer has booted, power cycle the camera
5. When the LED stops blinking, restart 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 Iris Scientific CMOS camera is selected in the imaging software application.
3. Power off the camera and the host computer and check all system connections (particularly the DATA and power cables), then restart.
4. Confirm the camera is operational by taking an image with a standard C-mount (Iris 9) / F-mount (Iris 15) 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 external cooling fins 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 number code and contact Teledyne Photometrics Customer Service.

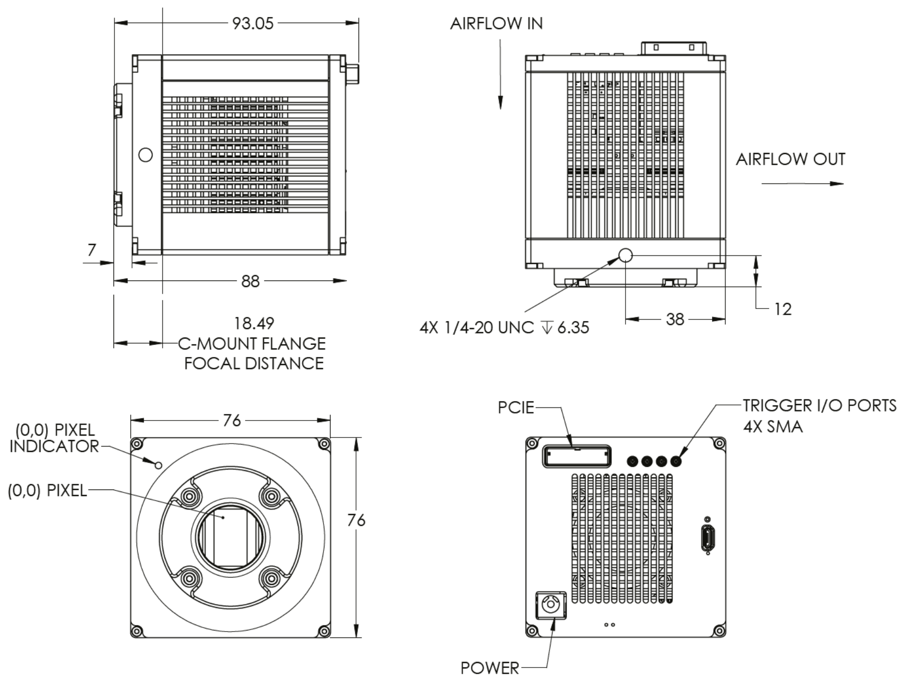
Lengthy Pause During Imaging

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.

Chapter 6 – Basic Specifications

Iris Scientific CMOS: Front, Side And Rear Views



Camera Weight

Weight: 1.5lbs., 0.68kg

Sensor Specifications

Window	UV grade fused-silica Broadband MgF2 anti-reflective coating on both surfaces
Scientific CMOS Sensor Array	
Sensor	GPixel GSense 5130 Scientific CMOS sensor
Sensor Process	Microlens array
Resolution (Iris 9)	2960 x 2960 (9 Megapixel)
Resolution (Iris 15)	5056 x 2960 (15 Megapixel)
Pixel Size (Iris 9)	4.25µm x 4.25µm
Pixel size (Iris 15)	4.25µm x 4.25µm
Digitization (Readout) Rate	480 MHz

Power Supply Specifications

Voltage Input:	100-240 V~ @ 50-60 Hz
Current Input:	5 A (110V nominal)
Voltage Output:	+12V @ 8 A
Maximum Power Output:	140 W
Supply Cable Length:	4 ft. / 1.22 m
Certifications:	CE, UL, CUL, FCC, PSE Efficiency level VI

Note: CE certification applies to the Iris camera only when the camera system operates with a CE-approved power supply

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