



TELEDYNE PRINCETON INSTRUMENTS
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Part of the Teledyne Imaging Group

SOPHIA[®]-XO System Manual



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Revision History

Issue	Date	List of Changes
Issue 3	March 27, 2019	Issue 3 of this document incorporates the following changes: <ul style="list-style-type: none"> • Rebranded as Teledyne Princeton Instruments.
Issue 2	November 3, 2017	Issue 2 of this document incorporates the following changes: <ul style="list-style-type: none"> • Added support for CCD42-40; • Added Appendix D, Drain Coolant from SOPHIA-XO; • Added Section 6.3.1, Experiment Shutdown.
Issue 1	December 19, 2016	This is the initial release of this document.

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Chapter 1: About this Document

Thank you for purchasing a SOPHIA-XO camera system from Teledyne Princeton Instruments. Since 1981, Teledyne Princeton Instruments has been the legendary name behind the most revolutionary spectroscopy and imaging products for cutting edge research.

Please read the manual carefully before operating the camera. This will help you optimize the many features of this camera to suit your research needs.

If you have any questions about the information contained in this manual, contact the Teledyne Princeton Instruments customer service department. Refer to [Contact Information](#) on page 136 for complete contact information.

1.1 Intended Audience

This user manual is intended to be used by scientists and other personnel responsible for the installation, setup, configuration, and acquisition of imaging data collected using a SOPHIA-XO system.

This document provides all information necessary to safely install, configure, and operate the SOPHIA-XO, beginning with the system's initial installation.

1.2 Related Documentation

[Table 1-1](#) provides a list of related documentation and user manuals that may be useful when working with the SOPHIA-XO camera system. To guarantee up-to-date information, always refer to the current release of each document listed.

Table 1-1: Related Documentation

Document Number	Document Title
-	LightField 6 Online Help
-	SOPHIA-XO Camera System Data Sheet
Varies	Spectrograph User Manual
4411-0134	PICam 3.x Programmers' Manual
4411-0155	PICam 4.x Programmers' Manual
4411-0161	PICam 5.x Programmers' Manual

Teledyne Princeton Instruments maintains updated documentation and user manuals on their FTP site. Visit the Teledyne Princeton Instruments FTP Site to verify that the most recent user manual is available and being referenced:

ftp://ftp.piacton.com/Public/Manuals/Princeton_Instruments

<ftp://ftp.piacton.com/Public/Manuals/Acton>

1.3 Document Organization

This manual includes the following chapters and appendices:

- [Chapter 1, About this Document](#)
This chapter provides information about the organization of this document, as well as related documents, safety information, and conventions used throughout the manual.
- [Chapter 2, SOPHIA-XO Camera System](#)
This chapter provides information about the components included with a standard SOPHIA-XO camera system, as well as options that are available for purchase from Teledyne Princeton Instruments.
- [Chapter 3, Install LightField](#)
This chapter provides information about the installation of Teledyne Princeton Instruments' LightField image acquisition software.
- [Chapter 4, System Block Diagrams](#)
This chapter provides high-level block diagrams of typical system configurations.
- [Chapter 5, System Verification](#)
This chapter provides a step-by-step procedure for placing a SOPHIA-XO camera system in operation for the first time when using Teledyne Princeton Instruments' LightField 64-bit data acquisition software.
- [Chapter 6, Hardware Configuration](#)
This chapter provides information about the installation and configuration of system hardware.
- [Chapter 7, Exposure](#)
This chapter provides information about factors that affect the signal acquired on the array, including array architecture, exposure time, temperature, and saturation.
- [Chapter 8, Analog to Digital Conversion](#)
This chapter provides information about the configuration of Analog-to-Digital Conversion parameters.
- [Chapter 9, Full Frame Readout](#)
This chapter provides information about Full Frame Readout operation and related parameter configuration.
- [Chapter 10, Kinetics Readout](#)
This chapter provides information about Kinetics operation and related parameter configuration.
- [Chapter 11, Binning](#)
This chapter provides information about the configuration of Hardware and Software binning.
- [Chapter 12, Shutter Configuration and Control](#)
This chapter provides information about the configuration of shutter control parameters.
- [Appendix A, Technical Specifications](#)
This appendix provides CCD, system, and other basic specifications for a SOPHIA-XO system.
- [Appendix B, Outline Drawings](#)
This appendix provides outline drawings of the SOPHIA-XO camera and power supply.

- [Appendix C, Custom Modes](#)
This appendix provides information necessary to configure custom chip modes on the SOPHIA-XO.
- [Appendix D, Drain Coolant from SOPHIA-XO](#)
This appendix provides information about how to safely drain coolant from the SOPHIA-XO camera body.
- [Appendix E, Backfilling for Storage or Shipment](#)
Provides the procedure to backfill a SOPHIA-XO with nitrogen for storage or shipment.
- [Chapter F, Troubleshooting](#)
This appendix provides recommended troubleshooting information for issues which may be encountered while working with a SOPHIA-XO camera system.
- [Warranty and Service](#)
This section provides warranty information for the SOPHIA-XO. Contact information is also provided.

1.4 Safety Related Symbols Used in this Manual

The following safety symbols are used throughout this manual.



CAUTION!

A **Caution** provides detailed information about actions and/or hazards that may result in damage to the equipment being used, including but not limited to the possible loss of data.



WARNING!

A **Warning** provides detailed information about actions and/or hazards that may result in personal injury or death to individuals operating the equipment.



WARNING! RISK OF ELECTRIC SHOCK!

The use of this symbol on equipment indicates that one or more nearby items pose an electric shock hazard and should be regarded as potentially dangerous. This same symbol appears in the manual adjacent to the text that discusses the hardware item(s) in question.

1.5 SOPHIA-XO Safety Information

Before turning on the power supply, the ground prong of the power cord plug must be properly connected to the ground connector of the wall outlet. The wall outlet must have a third prong, or must be properly connected to an adapter that complies with these safety requirements.



WARNINGS!

1. If the SOPHIA-XO camera system is used in a manner not specified by Teledyne Princeton Instruments, the protection provided by the equipment may be impaired.
 2. If the equipment or the wall outlet is damaged, the protective grounding could be disconnected. Do not use damaged equipment until its safety has been verified by authorized personnel. Disconnecting the protective earth terminal, inside or outside the apparatus, or any tampering with its operation is also prohibited.
-

Inspect the supplied power cord. If it is not compatible with the power socket, replace the cord with one that has suitable connectors on both ends.



WARNING!

Replacement power cords or power plugs must have the same polarity and power rating as that of the original ones to avoid hazard due to electrical shock.

1.6 Precautions

To prevent permanently damaging the SOPHIA-XO system, observe the following precautions at all times.



CAUTION!

1. The CCD array is very sensitive to static electricity. Touching the CCD can destroy it. Operations requiring contact with the device can only be performed at the factory.
 2. When using high-voltage equipment (e.g., an arc lamp,) with the camera system, be sure to turn the camera power ON LAST and turn the camera power OFF FIRST.
 3. Use caution when triggering high-current switching devices near the system (e.g., an arc lamp.) The CCD 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.
 4. Do not block air vents on the camera. Preventing the free flow of air overheats the camera and may damage it.
 5. If the SOPHIA-XO camera system is used in a manner not specified by Teledyne Princeton Instruments, the protection provided by the equipment may be impaired.
-

1.6.1 External Shutter

When using a SOPHIA-XO camera system with an External Shutter that has not been provided by Teledyne Princeton Instruments, contact the factory to properly configure the shutter driver. Refer to [Contact Information](#) on page 136 for complete information.



CAUTION!

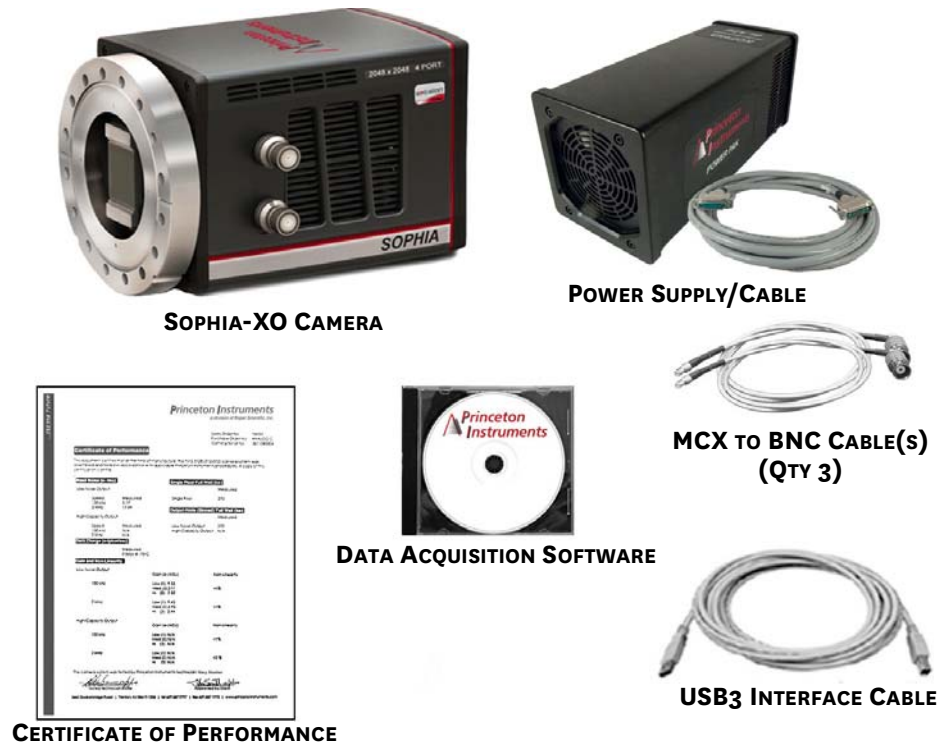
If a non-Teledyne Princeton Instruments/third-party shutter is connected to a SOPHIA-XO camera without first configuring the shutter driver, the shutter may not work, and the shutter and/or the SOPHIA-XO camera may be permanently damaged. Always contact Teledyne Princeton Instruments before connecting an external shutter that is not listed in [Table 2-4, Supported External Shutters](#), on page 24 to a SOPHIA-XO. Refer to [Contact Information](#) on page 136 for complete information.

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Chapter 2: SOPHIA-XO Camera System

This chapter provides an introduction to, and overview information about, Teledyne Princeton Instruments' SOPHIA-XO camera system. [Figure 2-1](#) shows those items that are typically included as part of a standard SOPHIA-XO Camera system.

Figure 2-1: Typical SOPHIA-XO System Components



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Standard items for a typical air-cooled system include:

- SOPHIA-XO Camera;
- Power Supply and Cable;
- USB3 Interface Cable;
- MCX to BNC Adapter Cables^a;
- Certificate of Performance;
- Data Acquisition Software, including Installation Disk and Hardware Key

a. Length may vary

Standard items for a typical liquid-cooled system include:

- SOPHIA-XO Camera;
- Power Supply and Cable;
- USB3 Interface Cable;
- MCX to BNC Adapter Cables^a;
- External Chiller/Circulator^b;
- Coolant Hoses^b;
- Certificate of Performance;
- Data Acquisition Software.

a. Length may vary

b. Not illustrated in [Figure 2-1](#).

2.1 SOPHIA-XO Camera

The SOPHIA-XO camera, illustrated in [Figure 2-2](#), is a fully integrated, ultra-low noise 2048 x 2048, 15 μm pixel CCD camera that utilizes back-illuminated CCDs without AR coating for direct detection of the widest range of X-rays between ~ 10 eV and 30 keV. Designed utilizing Teledyne Princeton Instruments' exclusive ArcTec™ thermoelectric cooling technology, SOPHIA-XO is the only camera that offers cooling down to -90°C with air-assist, liquid-assist, or air plus liquid assist for complete worry-free operation. The rotatable ConFlat flange with high vacuum seal design, software selectable gains, and readout speeds make these cameras well suited for ultra-high vacuum applications.

Figure 2-2: Typical SOPHIA-XO Camera



4411-0158_0002

SOPHIA-XO camera systems offer all basic CCD camera functions, such as Region of Interest (ROI) selection and binning, all under software control. It also provides advanced triggered operation as well as programmable TTL output.

2.1.1 Power

All voltages required by SOPHIA-XO camera systems are generated and delivered by an external power supply included with each SOPHIA-XO camera using the supplied cables.



CAUTION!

Use of a power supply other than that provided with the SOPHIA-XO camera will void the camera warranty. For specific power supply requirements, contact Teledyne Princeton Instruments. Refer to [Contact Information](#) on page 136 for complete information.

The receptacle on the power supply should be compatible with the line-voltage line cords in common use in the region to which the system is shipped. If the power supply receptacle is incompatible, a compatible adapter should be installed on the line cord, taking care to maintain the proper polarity to protect the equipment and assure user safety.

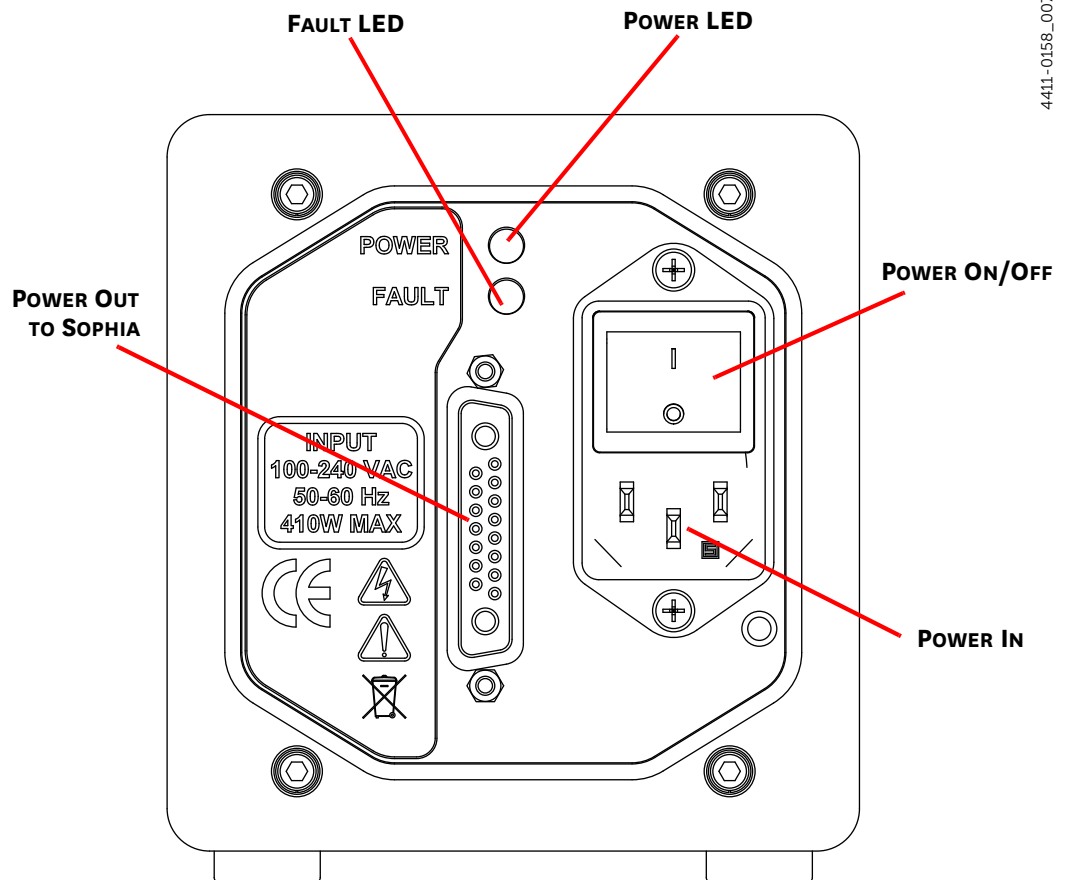
Figure 2-3 shows the connectors and indicators found on the rear of the SOPHIA-XO power supply.



REFERENCES:

Refer to [Section A.3, Power Specifications](#), on page 109 for complete voltage specifications.

Figure 2-3: SOPHIA-XO Power Supply Connectors and Indicators



Refer to [Table 2-2](#) for information about each connector and indicator on the power supply.

Table 2-1: SOPHIA-XO Power Supply Connectors and Indicators (Sheet 1 of 2)

Label	Description
Power Out	Provides necessary power and signals to SOPHIA-XO.
Fault LED	This Red LED is normally extinguished. When illuminated or flashing, this LED indicates a fault within the system has been detected. Refer to Appendix F, Troubleshooting , on page 123 for additional information.
Power LED	When illuminated, this Green LED indicates that the power supply is turned on. When extinguished, the power supply is turned off.

Table 2-1: SOPHIA-XO Power Supply Connectors and Indicators (Sheet 2 of 2)

Label	Description
Power On/Off	This switch is used to turn the power supply ON (1) and OFF (0).
Power In	This connector is used to connect the power supply to an AC wall receptacle using the provided power cable.

2.1.2 CCD Array

The SOPHIA-XO camera system, equipped with a ConFlat flange mount, incorporates a back-illuminated, scientific-grade CCD to ensure the highest image fidelity, resolution, and acquisition flexibility required for scientific imaging. Large full wells, square pixels, and 100% fill factors provide high dynamic range and excellent spatial resolution. Your choice of CCD is already installed in the camera that you received and has been individually tested.

For complete specifications and information about the CCD used in SOPHIA-XO cameras, refer to [Table A-2, CCD Array Specifications](#), on page 107.

2.1.3 Cooling

Dark current is reduced in SOPHIA-XO camera systems by cooling the CCD array using Teledyne Princeton Instruments' exclusive ArcTec™ technology using air and/or circulating coolant. To prevent condensation and contamination from occurring, cameras cooled this way are evacuated. Refer to [Table A-3, Default Operating Temperature](#), on page 108 for specific cooling specifications.

2.1.3.1 Internal Fan

The SOPHIA-XO camera is equipped with an internal cooling fan that:

- Removes heat and assists in the cooling of the CCD array, and
- Cools the electronics.

Teledyne Princeton Instruments ArcTec cooling technology cools SOPHIA-XO's CCD assisted by air drawn into the camera by an internal fan mounted on the rear of the camera. The circulating air then vents out through slots on the side panels. By default, the fan is always in operation and air-cooling of both the CCD and the internal electronics occurs continuously. In most cases, the low-vibration fan action does not adversely affect image acquisition.

In those applications where the fan's vibration could reduce image quality the internal fan can be disabled on the Sensor Expander within LightField.

- When SOPHIA-XO is air cooled (i.e., no external coolant circulator is in use,) the internal fan can be disabled for a brief period (i.e., a few seconds.) Sensors within SOPHIA-XO monitor its temperature and will reactivate the fan before temperatures within the camera rise too much.
- When SOPHIA-XO is cooled using an external coolant circulator, the internal fan can be safely disabled for a longer period. As with air cooled applications, internal sensors monitor the temperature and will reactivate the fan if necessary.

For the fan to function properly, uninhibited air circulation must be maintained between the sides of the camera and the laboratory atmosphere.

2.1.3.2 External Coolant Circulator

SOPHIA-XO cameras can be cooled by circulating coolant providing a low vibration system for data acquisition. The coolant circulator can be any commercially available circulator provided it is capable of continuously pumping a 50:50 mixture of room temperature (23°C) water and ethylene glycol at 1 liter per minute. Refer to [Section A.5, External Coolant Circulator Specifications](#), on page 110 for additional information. If desired, contact Teledyne Princeton Instruments for additional recommendations. Refer to [Contact Information](#) on page 136 for complete information.



CAUTION!

Never set the external coolant temperature below the dew point.

Coolant temperature should not be below the dew point of the ambient air. Internal condensation caused by operation below the dew point may damage the camera and will void the warranty. Additionally, the SOPHIA-XO monitors its internal temperature and will automatically restart its fan regardless of the software settings if it senses excessive internal heat buildup.

2.1.3.3 Coolant Ports

SOPHIA-XO cameras are equipped with cooling ports that allow it to be connected to an external coolant circulator. As is the case with circulating air, circulating coolant removes heat produced by the camera. This means of heat removal is designed for vibration-free data acquisition. For the circulating coolant to function properly, free air circulation must be maintained between the sides of the external coolant circulator and the laboratory atmosphere.



WARNING!

NEVER apply negative pressure to the liquid circulator fittings on the SOPHIA-XO camera. Doing so may permanently damage the camera.



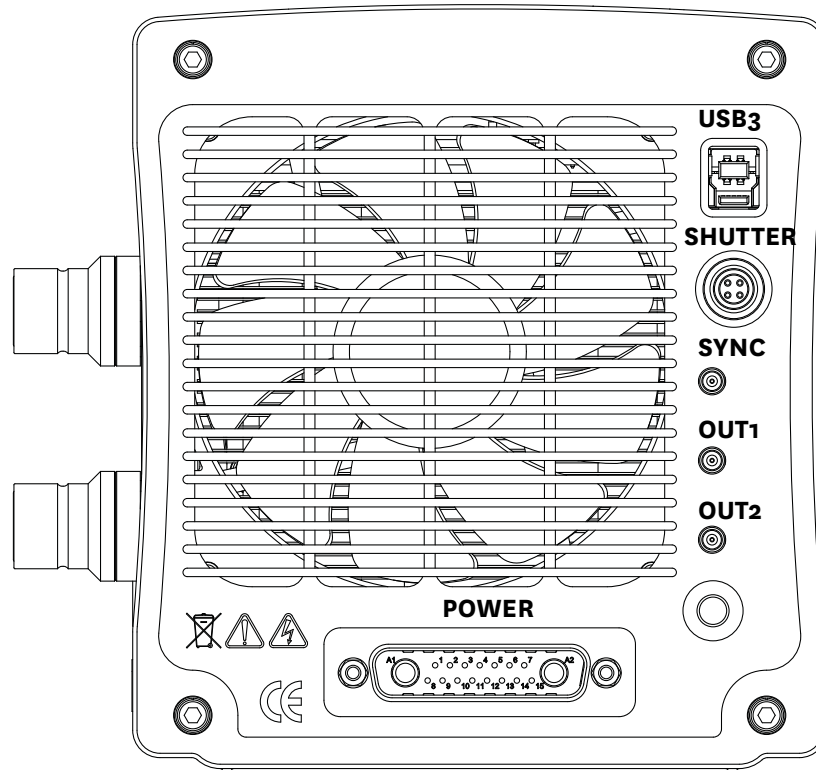
CAUTION!

The wetted areas of the SOPHIA-XO heat exchanger and fittings are nickel plated.

2.1.4 SOPHIA-XO Rear-Panel Connectors

Figure 2-4 illustrates the rear-panel connectors on a SOPHIA-XO camera.

Figure 2-4: SOPHIA-XO Rear-Panel Connectors



4411-0158_0003

Refer to [Table 2-2](#) for information about each rear-panel connector.

Table 2-2: SOPHIA-XO Rear-Panel Connectors (Sheet 1 of 2)

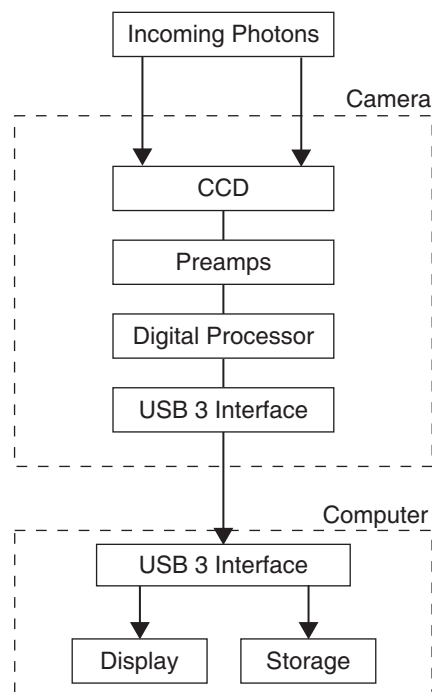
Label	Description
USB3	Control signals and data are transmitted between the camera and host computer via this port.
SHUTTER	4-pin circular connector to connect an external shutter to SOPHIA-XO. NOTE: Refer to Section 12.2, Using an External Shutter , on page 103 for complete information about installing, utilizing, and configuring an external shutter.
SYNC	0 – +5.0 V _{DC} TTL-compatible logic level input with a 10 k Ω pull-up resistor. Allows data acquisition and readout to be synchronized with external events. Positive or negative edge triggering is programmable. CAUTION: Do not apply a voltage greater than +5.0 V _{DC} to this input. Doing so may permanently damage the SOPHIA-XO camera.
OUT1	0 to +5.0 V _{DC} programmable TTL-compatible logic level output capable of driving logic levels into 50 Ω . This output can be programmed and inverted via the application software.

Table 2-2: SOPHIA-XO Rear-Panel Connectors (Sheet 2 of 2)

Label	Description
OUT2	0 to +5.0 V _{DC} programmable TTL-compatible logic level output capable of driving logic levels into 50 Ω. This output can be programmed and inverted via the application software.
POWER	Power input from external power supply provided with the SOPHIA-XO system.

2.1.5 Theory of Operation




During data acquisition, the CCD array is exposed to a source and charge accumulates in the pixels. After the defined exposure time, the accumulated signal is readout of the array, digitized, and transferred to the host computer. Upon data transfer, the data are displayed and/or stored via application software. This sequence is illustrated by the block diagram shown in [Figure 2-5](#).

Figure 2-5: Light Path Block Diagram for SOPHIA-XO Systems

2.2 Cables

Table 2-3 describes the cables included with a standard SOPHIA-XO Camera System.

Table 2-3: Standard SOPHIA-XO Camera System Cables

Cable	Part Number	Description/Purpose	Length
Power Cable	6050-0714	Primary power cable connecting the SOPHIA-XO to the external power supply. See Figure 2-4 .  4411-0158_0103	3 m [9.8 ft]
USB 3	6050-0733	Connects the USB 3 connector on the rear of the SOPHIA-XO with a USB card installed in the host computer. See Figure 2-4 .  4411-0158_0004	3 m [9.8 ft]
MCX to BNC	6050-0540	Three (3) MCX to BNC adapter cables are included. These connect to the SYNC, OUT1, and OUT 2 connectors on the rear of the SOPHIA-XO. See Figure 2-4 .  4411-0158_0005	Varies

2.3 Certificate of Performance

Each SOPHIA-XO camera is shipped with a Certificate of Performance which states that the camera system has been assembled and tested according to approved Teledyne Princeton Instruments procedures. It documents the camera's performance data as measured during the testing of the SOPHIA-XO and lists the following camera- and customer-specific information:

- Sales Order Number;
- Purchase Order Number;
- Camera Serial Numbers

This information is useful when contacting Teledyne Princeton Instruments Customer Support.

2.4 Application Software

Teledyne Princeton Instruments offers a number of data acquisition software packages for use with SOPHIA-XO camera systems, including:

- **LightField®**
The SOPHIA-XO camera can be operated using LightField, Teledyne Princeton Instruments' 64-bit Windows® compatible software package.
LightField combines complete control over Teledyne Princeton Instruments' cameras and spectrographs with easy-to-use tools for experimental setup, data acquisition and post-processing. LightField makes data integrity priority #1 via automatic saving to disk, time stamping and retention of both raw and corrected data with full experimental details saved in each file. LightField works seamlessly in multi-user facilities, remembering each user's hardware and software configurations and tailoring options and features accordingly. The optional, patent-pending IntelliCal™ package is the highest-performance wavelength calibration software available, providing up to 10X greater accuracy across the entire focal plane than competing routines.
- **PICam**
The standard 64-bit software interface for cooled CCD cameras from Teledyne Princeton Instruments. PICam is an ANSI C library of camera control and data acquisition functions.
Refer to the appropriate PICam Programmers' Manual for the list of supported operating systems. Refer to [Table 1-1, Related Documentation](#), on page 9 for additional information.
- **Scientific Imaging ToolKit™ (SITK™)**
A collection of LabVIEW® VIs for scientific detectors and spectrographs. This third party software can be purchased from Teledyne Princeton Instruments.



NOTE:

SOPHIA-XO cameras may also be operated by several other third-party software packages. Please check with the providers of the packages for compatibility and support information.

2.5 Accessories

Teledyne Princeton Instruments offers a number of optional accessories that are compatible with SOPHIA-XO. For complete ordering information, contact Teledyne Princeton Instruments.

2.5.1 External Shutters

Teledyne Princeton Instruments offers a variety of external shutters that are compatible with, and supported by, SOPHIA-XO cameras. Refer to [Table 2-4](#) for the list of external shutters that are supported by SOPHIA-XO.



CAUTION!

In order to prevent potential permanent damage to either the SOPHIA-XO camera and/or the shutter, always contact Teledyne Princeton Instruments before connecting an external shutter that is not listed in [Table 2-4](#) to a SOPHIA-XO. Refer to [Contact Information](#) on page 136 for complete information.

Table 2-4: Supported External Shutters

Description	Aperture
Vincent VS25	25 mm
Vincent VS35	35 mm
Vincent CS25	25 mm
Vincent CS45	45 mm
PRONTOR Magnetic 0	23 mm
PRONTOR Magnetic E/40	40 mm



NOTE:

Refer to [Table A-7, SOPHIA-XO External Shutter \(Non-X-Ray\) Specifications](#), on page 110 for technical specifications for supported non-X-ray shutters.

Contact Teledyne Princeton Instruments for information about ordering an external shutter for use with SOPHIA-XO. Refer to [Contact Information](#) on page 136 for complete information.

2.5.1.1 X-Ray Shutters

Contact Teledyne Princeton Instruments for information about ordering an external x-ray shutter for use with SOPHIA-XO. Refer to [Contact Information](#) on page 136 for complete information.

2.6 Unpack the System

All required items should be included with the shipment. The SOPHIA-XO system has been manufactured according to the camera options specified at the time of purchase, including the CCD window and coatings that were ordered.

When unpacking the system, examine the system components for any signs of shipping damage. If there are any, notify Teledyne Princeton Instruments immediately and file a claim with the carrier. Be sure to save the shipping carton for inspection by the carrier. If damage is not apparent but system specifications cannot be achieved, internal damage may have occurred in shipment.

Retain all original packing materials so that the SOPHIA-XO system can be easily and safely packaged and shipped to another location or returned for service if necessary. If assistance is required at any time, contact Teledyne Princeton Instruments Customer Support. Refer to [Contact Information](#) on page 136 for complete information.

2.6.1 Shipping Plate

A shipping plate mounted to the open nose of the SOPHIA-XO camera protects the interior of the camera from contamination or damage during shipment. Before shipment, the shipping plate is mounted to the camera and the camera is backfilled with dry Nitrogen to a pressure of 1 Atmosphere absolute via the valve and fill port on the edge of the plate.

The shipping plate includes an integral C-mount lens for first light verification of camera operation. After confirming the setup, remove the shipping plate and store it and its mounting hardware in a safe location. Before storing or shipping the camera, install the shipping plate and backfill the camera with dry Nitrogen to a pressure of 1 Atmosphere absolute. Refer to [Appendix E, Backfilling for Storage or Shipment](#), on page 121 for complete information.

2.6.2 Verify Equipment and Parts Inventory

Verify all equipment and parts required to set up the SOPHIA-XO system have been delivered.

A typical system consists of:

- SOPHIA-XO Camera;
- Power Supply and Cable;
- USB3 Interface Cable;
- MCX to BNC Adapter Cables^a;
- Certificate of Performance;
- Data Acquisition Software, including:
 - Installation disk;
 - Hardware Key

a. Length May Vary

Accessories that may have been purchased include:

- External Shutter(s).

2.7 SOPHIA-XO Camera and System Maintenance



WARNING!

Turn off all power to the equipment and secure all covers before cleaning the unit. Otherwise, damage to the equipment or injury to you could occur.

2.7.1 Camera

Although there is no periodic maintenance that needs to be performed on a SOPHIA-XO camera, users are advised to wipe it down with a clean damp cloth from time to time. This operation should only be done on the external surfaces and with all covers secured. In dampening the cloth, use clean water only. No soap, solvents or abrasives should be used. Not only are they not required, but they could damage the finish of the surfaces on which they are used.

2.7.2 Storage

Before storing the SOPHIA-XO camera, install the shipping plate and backfill the camera with dry Nitrogen to a pressure of 1 Atmosphere absolute via the valve and the fill port located on the edge of the plate. Refer to [Appendix E, Backfilling for Storage or Shipment](#), on page 121 for complete information.

2.7.3 Repairs

Because the SOPHIA-XO camera system contains no user-serviceable parts, repairs must be performed by Teledyne Princeton Instruments. Should the system need repair, contact Teledyne Princeton Instruments customer support for instructions. Refer to [Contact Information](#) on page 136 for complete information.

Save the original packing materials and use them whenever shipping the system or system components.

Chapter 3: Install LightField

This chapter provides the installation procedure for LightField application software.



NOTE:

If LightField has already been successfully installed on the host computer, this chapter may be skipped.

3.1 Prerequisites

Before beginning to install LightField, verify that:

- The operating system on the desired host computer is Windows® 7/8/10 (64-bit);
- The host computer supports USB3;
If it does not support USB3, refer to the host computer manufacturer's instructions for installing a USB3 interface card;
- The installation disk and hardware key are available.

3.2 Installation Procedure

Perform the following procedure to install LightField on the host computer:

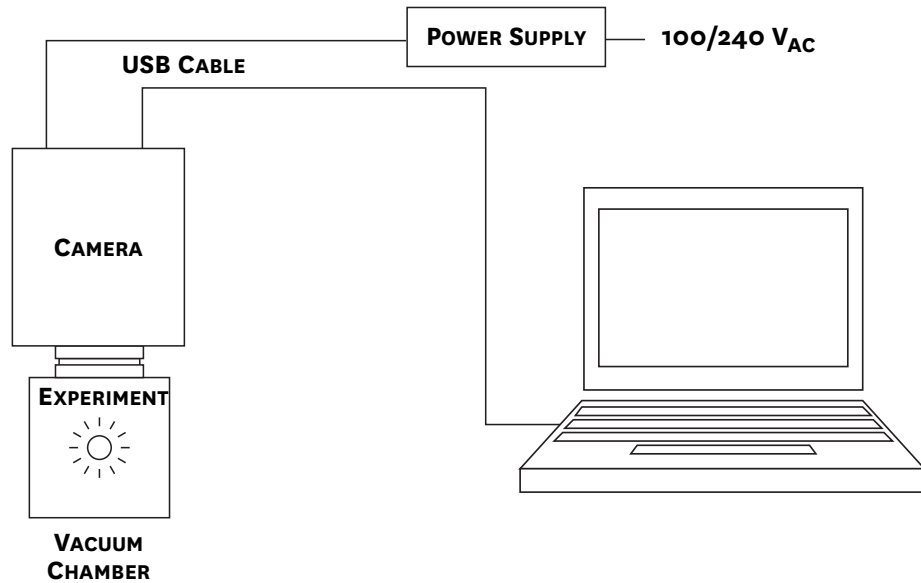
1. Insert the LightField Installation CD into the CD drive on the host computer, and follow the on-screen prompts.
2. After the installation has been completed, reboot the host computer.
3. Connect the SOPHIA-XO system components to the host computer and apply power.
4. Launch LightField, activate it, and begin experiment configuration.

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Chapter 4: System Block Diagrams

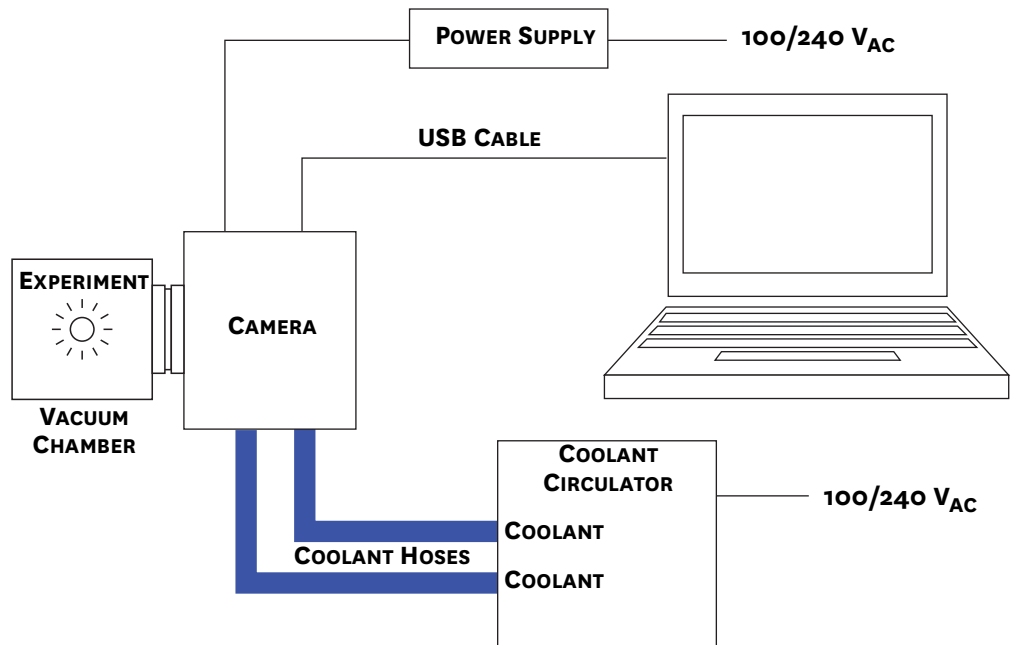
This section provides block diagrams of typical system configurations.

Figure 4-1: Block Diagram: Typical Air-Cooled Experiment



4411-0158_0012

Figure 4-2: Block Diagram: Typical Liquid-Cooled Experiment



4411-0158_0014

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Chapter 5: System Verification

SOPHIA-XO cameras are designed without a protective window and are therefore shipped from the factory with a shipping plate installed.



WARNING!

The shipping plate must remain in place until camera operation has been verified as described in this chapter. Once camera operation has been verified, the SOPHIA-XO can be mounted to a vacuum chamber for normal operation. Refer to [Section 6.1, Mount SOPHIA-XO to a Vacuum Chamber](#), on page 37 for complete information.



WARNING!

Long term exposure of the CCD array to the environment increases the probability of physical damage to the array, ESD damage, and contamination of the CCD array surface.



NOTE:

Removing the shipping plate voids the warranty on the CCD array. Do not remove this shipping plate until camera operation has been verified according to the procedure detailed in this chapter.

5.1 Initial Hardware Configuration

This section provides step-by-step instructions for acquiring an image in LightField and verifying proper initial SOPHIA-XO operation. Once system operation has been verified, the SOPHIA-XO can be mounted to a vacuum chamber as described in [Section 6.1, Mount SOPHIA-XO to a Vacuum Chamber](#), on page 37.



NOTE:

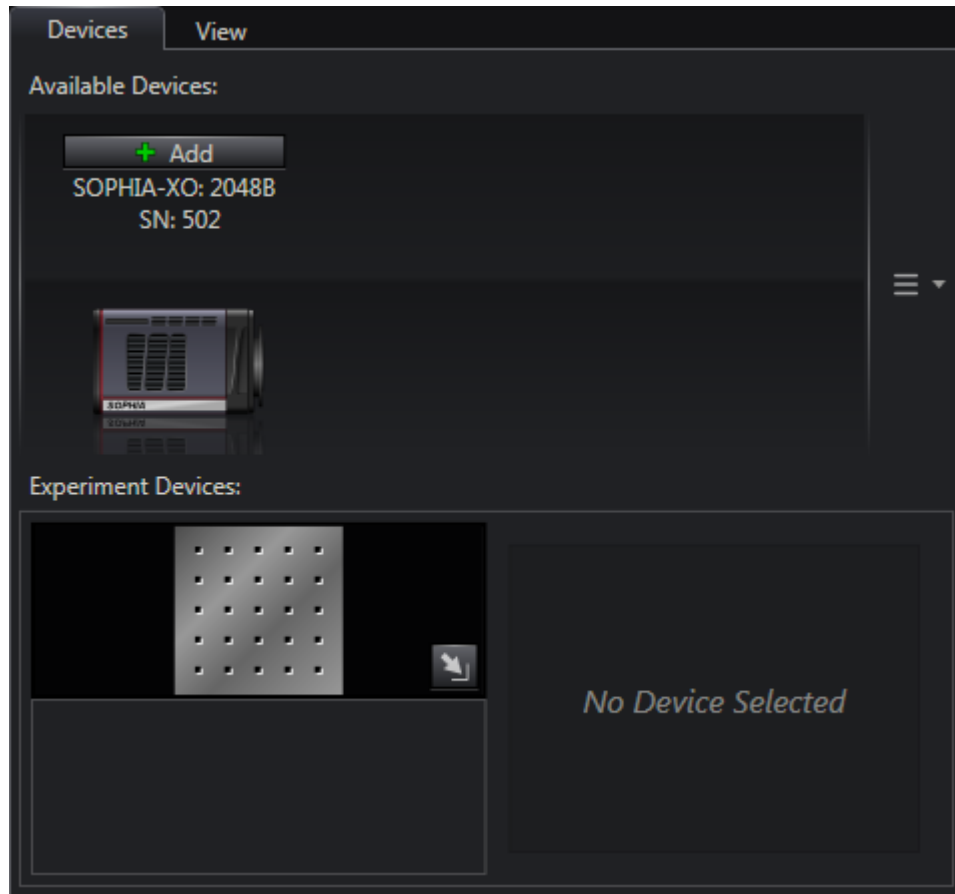
Verify that the protective shipping plate has not been removed before performing this procedure.

Perform the following procedure to set up and configure the system to acquire an image:

1. Mount a test target in front of the camera.
2. Turn on the SOPHIA-XO.
3. Turn on the host computer.
4. Launch LightField.

5. Once LightField has launched, a SOPHIA-XO camera icon will be shown in the Devices area. See [Figure 5-1](#).

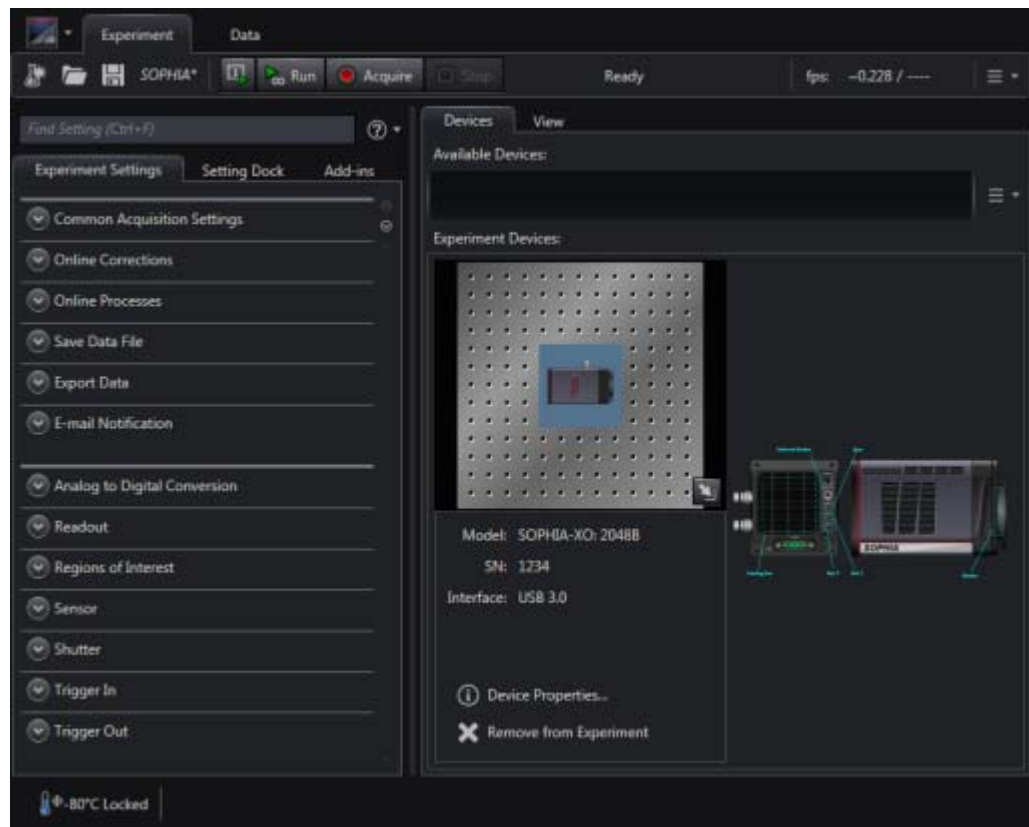
Figure 5-1: Available Devices Area



6. Drag the SOPHIA-XO icon into the Experiment Devices area.

7. The Experiment Settings stack on the left includes several expanders. Since this is a new experiment, the default configuration settings for the camera are preconfigured. See [Figure 5-2](#).

Figure 5-2: Experiment Devices Area



The Status bar across the bottom of the window includes an icon for temperature status. Temperature Status reports the current system temperature and whether the set temperature has been reached. Clicking on the icon opens the Sensor expander in which the desired temperature can be configured.



NOTE:

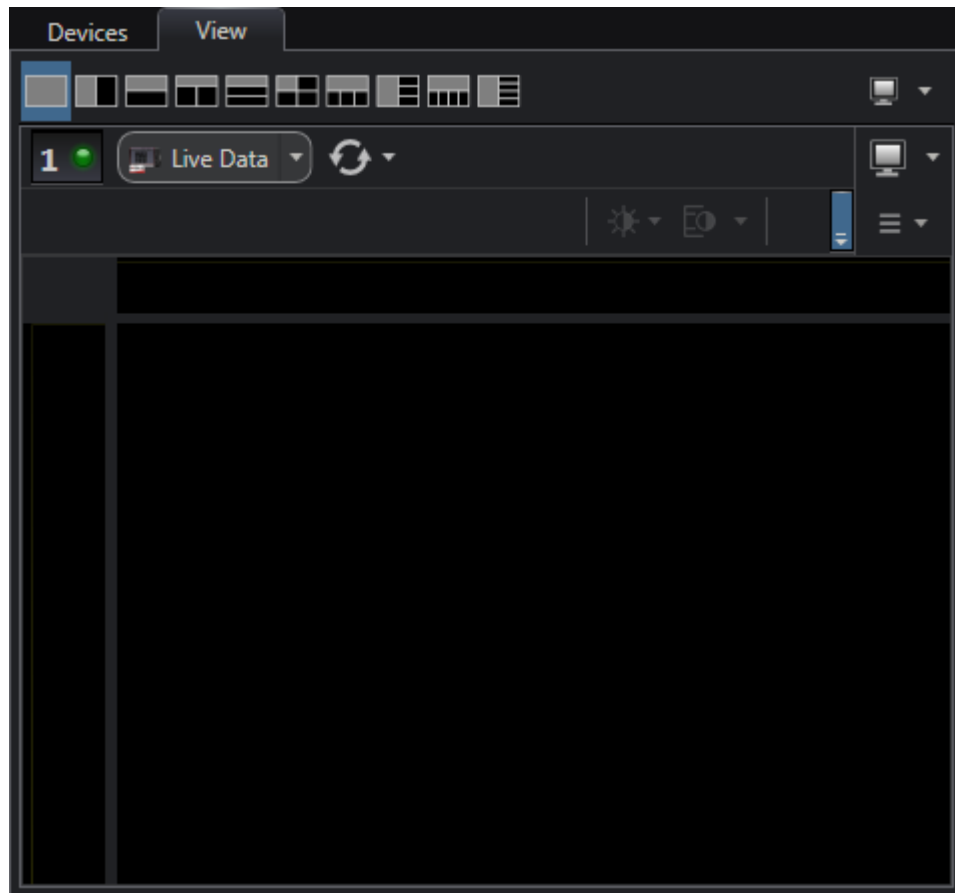
Each SOPHIA-XO camera is carefully calibrated at the factory for optimum performance at low CCD temperatures. If operated at warmer temperatures, such as during system cool down or if the temperature set point is set warmer than the factory-calibrated temperature, the camera might not image properly. Artifacts in the image, fixed value pixels, or lack of imaging in one or more quadrants may occur.

5.1.1 Data Acquisition

Perform the following procedure to acquire live data:

1. Click on the View tab located above Available Devices to change focus to the View area. See [Figure 5-3](#).

Figure 5-3: View Area




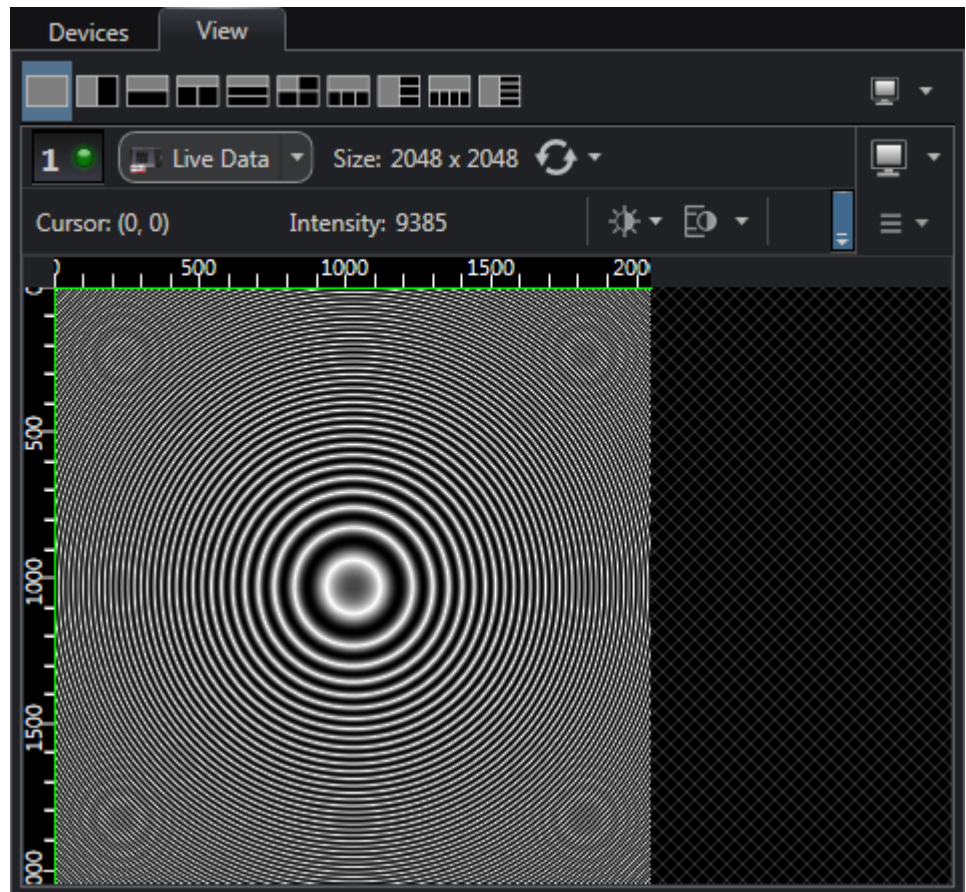
- Click Run  to initiate Preview mode.
In this mode, images are continuously acquired and displayed. See [Figure 5-4](#).

Figure 5-4: View Area Displaying an Image



3. Adjust the lens aperture, intensity scaling, and focus for the best image as viewed on the computer monitor.

Imaging tips include:

- Begin with the lens blocked off and then set the lens at the smallest possible aperture (i.e., the largest f-stop.)
- When using a camera without a shutter, it should remain in a dark environment, and a long exposure used in order to avoid image smearing.
- Verify there is a suitable target in front of the lens. An object with text or graphics works best.
- Inspect the brightest regions of the image to determine if the A/D converter is at full-scale.

**NOTE:**

A 16-bit A/D is at full scale when the brightest parts of the image reach an intensity of 65535.

Adjust the aperture so that it is slightly smaller (i.e., a higher f-stop,) than the setting where maximum brightness occurs on any spot of the image.

- Set the focus adjustment of the lens for maximum sharpness in the viewed image.
4. After the camera has been successfully focused, either:
 - Exit/stop Preview mode;
 - Continue Preview mode;
 - Begin Acquire mode.

5.2 System Shutdown

Perform the following procedure to shutdown the SOPHIA-XO system:

1. Exit LightField.
2. Turn off the light source.
3. Set the camera temperature to the 0°C and allow the CCD to warm up.
4. Once the camera has warmed to 0°C, turn off the camera power by moving the power supply switch from the 1 position to the 0 (ZERO) position.

Chapter 6: Hardware Configuration

This chapter provides information about mounting a SOPHIA-XO camera to a vacuum chamber, as well as instructions for installing optional accessories.

6.1 Mount SOPHIA-XO to a Vacuum Chamber

SOPHIA-XO cameras are designed without a protective window and are therefore shipped from the factory with a shipping plate installed.



WARNING!

The shipping plate must remain in place until camera operation has been verified as described in [Chapter 5, System Verification](#), on page 31. Once camera operation has been verified, the SOPHIA-XO can be mounted to a vacuum chamber for normal operation as described in this section.



WARNING!

Long term exposure of the CCD array to the environment increases the probability of physical damage to the array, ESD damage, and contamination of the CCD array surface.



NOTE:

Removing the shipping plate voids the warranty on the CCD array. Do not remove this shipping plate until camera operation has been verified according to the procedure detailed in this chapter.

Perform the following procedure to mount a SOPHIA-XO to a vacuum chamber:

1. Loosen and remove sixteen (16) bolts securing the shipping plate. Remove the shipping plate.

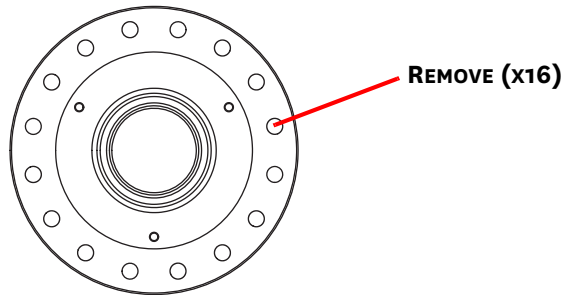


NOTE:

Before shipment, cameras are backfilled with dry Nitrogen at the factory to a pressure of 1 Atmosphere absolute.

See [Figure 6-1](#).

Figure 6-1: Typical SOPHIA-XO Shipping Plate



4411-0158_0099

2. Remove and discard the copper sealing gasket.
3. Retain all shipping materials (except the copper gasket just removed) for future use.
4. Clean the ConFlat flange sealing edges and grooves with a lint-free wipe and inspect the flange for any shipping damage before mounting the camera.
5. Remove the new copper sealing gasket and inspect it for any shipping damage.
6. Carefully seat the copper sealing gasket into the groove between the ConFlat flanges. If gasket retaining clamps are available, they may be used to hold the sealing gasket in place during installation.
7. Mate the ConFlat flange to the chamber. The outer flange mounting ring is able to be rotated. You must orient the outer flange to align the mounting holes correctly.
8. Immediately install a minimum of three (3) bolts (English or metric) to secure/support the camera.



NOTE:

Do not completely tighten any of these three bolts at this time as the camera must be properly aligned with the chamber.

9. Align the camera to the application at this time.
10. Install the remaining bolts into the ConFlat flange.
11. Use a 1/2" torque wrench to tighten all bolts to a torque of 180 in-lbs \pm 10 in-lbs.
12. Evacuate the chamber before applying power to the SOPHIA-XO camera.
13. Teledyne Princeton Instruments recommends a helium leak check upon initial vacuum pump down before operating the camera.

6.2 External Shutter Installation



CAUTION!

In order to prevent potential permanent damage to either the SOPHIA-XO camera and/or the shutter, always contact Teledyne Princeton Instruments before connecting an external shutter that is not listed in [Table 2-4, Supported External Shutters](#), on page 24 to a SOPHIA-XO. Refer to [Contact Information](#) on page 136 for complete information.

If using an external shutter, refer to the manufacturer's installation information when installing it into the experiment configuration.

6.3 External Coolant Circulator Use

For liquid-cooled cameras, an external coolant circulator provides a vibration-free method of heat removal. Perform the following procedure to connect an external coolant circulator to a liquid-cooled SOPHIA-XO camera:



NOTE:

For specific configuration information, refer to the manufacturer-supplied documentation included with the external coolant circulator.

1. Verify the camera and the circulator power switches are turned off.
2. Verify the coolant circulator is positioned a minimum of 6 inches (150 mm) below the SOPHIA-XO camera. The vertical distance should not exceed 10 feet (3 m). Typically, the camera is at table height and the circulator is on the floor.
3. Using the supplied cooling hoses, connect the two coolant ports on the external coolant circulator to the two coolant ports on SOPHIA-XO.



CAUTION!

Verify there are no kinks in hoses that may impede coolant flow. Lack of sufficient flow can seriously harm the detector. Any resulting damage is not covered under warranty.



NOTE:

Although there are no dedicated IN or OUT coolant ports on a SOPHIA-XO camera, Teledyne Princeton Instruments recommends that the lower port (depending on the camera's physical orientation,) be used for the coolant inlet for best efficiency.



NOTE:

Damage caused by water leaking into the SOPHIA-XO voids the warranty.

4. Verify that the reservoir on the external coolant circulator contains sufficient coolant as specified by its manufacturer. If additional coolant is required, use a 50:50 mixture of water and ethylene glycol to add sufficient coolant.
5. Replace the reservoir cap.

6. Plug the external circulator into a 100-240 V_{AC}, 47-63 Hz power source.
7. Turn the coolant circulator on.

**CAUTION!**

When configuring an external coolant circulator, adhere to the following:

- Coolant flow-rate should never exceed 0.8 gal/minute.
- Coolant pressure should never exceed 20psi.
- Never set the circulator temperature below the dew point.

8. Verify there are no leaks or air bubbles in the hoses.

**NOTE:**

Small air bubbles (approximately the size of bubbles in soda) are common, particularly immediately following start up. These bubbles do not prevent proper operation.

- If no problems are observed, proceed to step 9.
 - If there are leaks or air bubbles, turn the circulator off and correct the problem(s) by securing the hoses or adding more coolant to the reservoir. Turn the circulator back on. Recheck and if there are no problems, proceed to step 9.
9. Turn on the camera.
 10. Launch LightField.

6.3.1 Experiment Shutdown

Following the completion of a liquid-cooled experiment, perform the following procedure:

1. Turn off the SOPHIA-XO camera's power supply.
2. Turn off the external coolant circulator according to all manufacturer-supplied documentation and procedures.
3. If desired, carefully disconnect the coolant hoses from the SOPHIA-XO camera.

**WARNING!**

If the SOPHIA-XO is to be shipped, to avoid potential catastrophic damage to the camera, all coolant must be drained from it. Refer to [Appendix D, Drain Coolant from SOPHIA-XO](#), on page 117.

Chapter 7: Exposure

This chapter discusses factors that may affect the signal acquired on the CCD array, such as:

- Exposure Time;
- CCD Temperature;
- Dark Charge;
- Saturation.

7.1 Exposure Time

Exposure time is the time between commands sent by the data acquisition software to start and stop signal accumulation on the sensor.



NOTE:

Exposure time is configured on the Common Acquisition Settings expander.

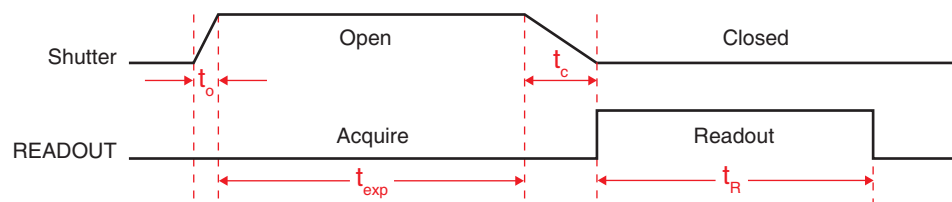
In combination with triggers these commands control when continuous cleaning of the CCD stops and when the accumulated signal will be read out.

Cleaning reduces the buildup of dark current and unwanted signal before the start of the exposure time. At the end of the exposure time, the CCD is readout and, depending on the specific experiment configuration:

- The next exposure begins (i.e., when configured for Free Run mode);
- Cleaning starts and continues until an incoming trigger is received (i.e., when configured for Trigger mode.)

Figure 7-1 illustrates how the exposure period is measured for a SOPHIA-XO. The Reading Out signal at the LOGIC OUT connector on the back of the SOPHIA-XO can be used to monitor the exposure and readout cycle (t_R) which is also shown in Figure 7-1.

Figure 7-1: Timing Diagram: CCD Exposure with Shutter Compensation



4411-0158_0025

where:

- t_o is the shutter opening compensation time;
This value is automatically configured for SOPHIA-XO.
- t_c is the shutter closing compensation time;
- t_{exp} is the exposure time;
- t_R is the readout time.

Note that the READOUT signal is:

- LOW during Shutter Open/Close Compensation Times;
- LOW during Exposure Time;
- HIGH during Readout.

Since the shutter behaves like an iris, the opening and closing of the shutter will cause the center of the CCD to be exposed slightly longer than the edges. It is important to realize this physical limitation, particularly when using short exposures.

**NOTE:**

A Shutter can overheat when short, rapidly repeated exposures are used, or if the shutter is held open for an extended period of time.

7.2 CCD Temperature

Lowering the temperature of the CCD will generally enhance the quality of the acquired signal. Temperature control is done on the Sensor expander.

Once a Temperature Setpoint has been programmed on the Sensor Expander, the software controls the camera's cooling circuits to reach the programmed array temperature.

When the camera's temperature has cooled to within $\pm 0.5^{\circ}\text{C}$ of the programmed setpoint, Locked is displayed to the right of the target temperature in LightField's status bar. At this point, SOPHIA-XO's control loop will continue to reduce the thermal error, typically holding the temperature to within $\pm 0.05^{\circ}\text{C}$ of the programmed setpoint.

The time required to achieve lock may vary considerably depending on factors such as the camera type, CCD array type, ambient temperature, etc. Ultimate system stability is achieved after approximately 20 minutes. However, as long as SOPHIA-XO's CCD has cooled sufficiently to image, focusing of the system can begin. Typically, quantitative data may be acquired as soon as thermal lock is relatively stable. If, however, an experiment requires exposure times in the 10 to 30 minutes range or more, it is recommended that SOPHIA-XO be permitted to cool for a longer period of time before acquiring live data.

**NOTE:**

It will be obvious if SOPHIA-XO has not yet cooled sufficiently by the poor quality of acquired images that are returned. Simply wait for the camera to cool before beginning to focus the system.

The deepest operating temperature for a system depends on the CCD array. Refer to [Table A-3, Default Operating Temperature](#), on page 108 for typical deepest cooling temperatures.

7.3 Dark Charge

Dark charge (or dark current) is the thermally induced buildup of charge in the CCD over time. The statistical noise associated with this charge is known as dark charge noise. Dark charge values vary widely from one CCD array to another and are exponentially temperature dependent. In the case of cameras with MPP type arrays, the average dark charge is extremely small. However, the dark-charge distribution is such that a significant number of pixels may exhibit a much higher dark charge, limiting the maximum practical exposure. Dark charge effect is more pronounced in the case of cameras having a non-MPP array (such as deep-depletion devices.)

With the light into the camera completely blocked, the CCD will collect a dark charge pattern, dependent on the exposure time and CCD temperature. The longer the exposure time and the warmer the camera, the larger and less uniform this background will appear. Thus, to minimize dark-charge effects, you should operate with the lowest CCD temperature possible.



CAUTION!

If a sudden change in the baseline signal is observed, there may be excessive humidity in the camera vacuum enclosure. Turn off the camera and contact Teledyne Princeton Instruments Customer Support. Refer to [Contact Information](#) on page 136 for complete contact information.

Do not be concerned about the DC level of this background. This is not noise but rather a subtractable bias pattern. By acquiring/saving a dark charge background image under conditions identical to those that will be used to acquire live data, this background image can then be subtracted from the acquired image, thus reducing dark-charge effects.

Although the dark charge pattern will be subtracted from the acquired image, both the dark charge pattern and the acquired image include system readout noise, N_R , which is additive. Therefore, when acquiring a dark charge pattern, it is strongly recommended that multiple frames of dark data be acquired and averaged since the cumulative noise within the dark background is reduced by the square root of the number of frames that have been averaged. The cumulative readout noise, which is the sum of the acquired image readout noise plus the dark data readout noise, is calculated as follows:

$$N_{RT} = \sqrt{N_R^2 + \frac{N_R^2}{F}}$$

where:

- N_{RT} = Total Readout Noise;
- N_R = Readout Noise;
- F = Number of Dark Pattern Frames Acquired.

For example, when acquiring one frame of dark data to generate the subtractable pattern, the dark pattern readout noise will be $\sim 1.414\sqrt{N_R}$, which is an increase of $\sim 41\%$ over the baseline readout noise. This value is calculated as follows:

$$\begin{aligned}
 N_{RT} &= \sqrt{N_R^2 + \frac{N_R^2}{F}} \\
 &= \sqrt{N_R^2 + \frac{N_R^2}{1}} \\
 &= \sqrt{N_R^2 + \frac{N_R^2}{1}} \\
 &= \sqrt{2N_R^2} \\
 &= 1.414N_R
 \end{aligned}$$

Refer to [Table 7-1](#) for typical noise penalty figures as a percentage of readout noise, N_R .

Table 7-1: Readout Noise Penalty vs Number of Acquired Frames

Number of Acquired Frames (F)	Noise Penalty ^a
1	41%
4	12%
8	6%
16	3%

a. Expressed as a percentage of N_R

7.3.1 Clean Until Trigger

When using an external trigger to initiate data readout, SOPHIA-XO supports Clean Until Trigger (CUT,) an additional level of cleaning/removing accumulated dark charge that continues until the moment the incoming trigger pulse is received.



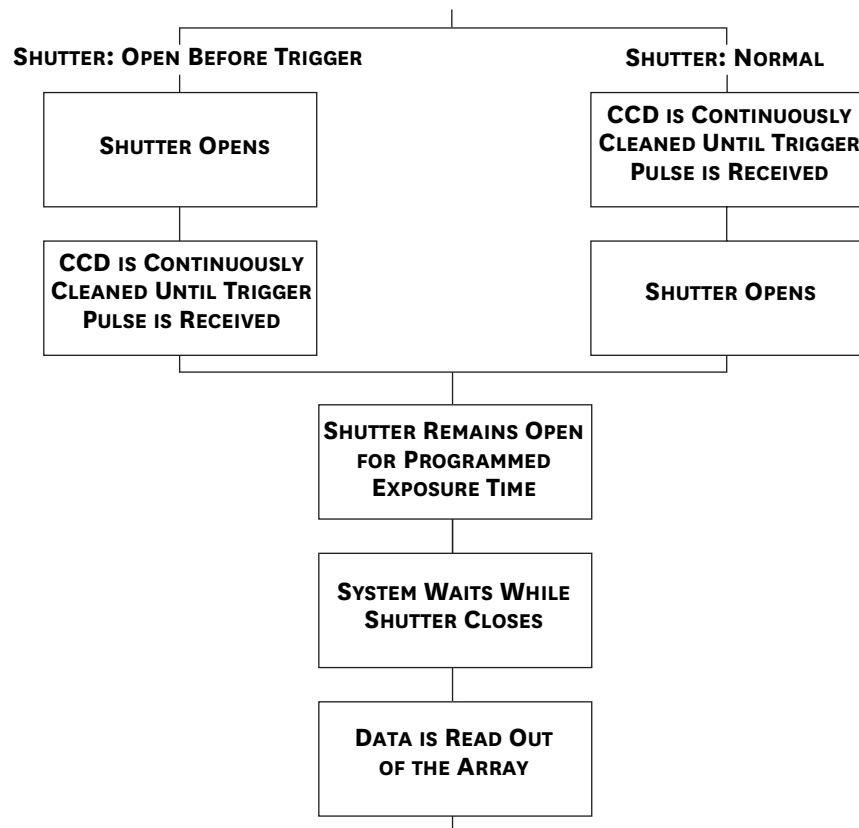
REFERENCES:

For information about the use and configuration of external triggers, refer to:

- [Section 9.2, Experiment Timing](#), on page 60, for Full Frame Mode;
- [Section 10.2, Experiment Timing](#), on page 79, for Kinetic Mode.

Figure 7-2 illustrates a flowchart of this mode.

Figure 7-2: Flowchart: Clean Until Trigger

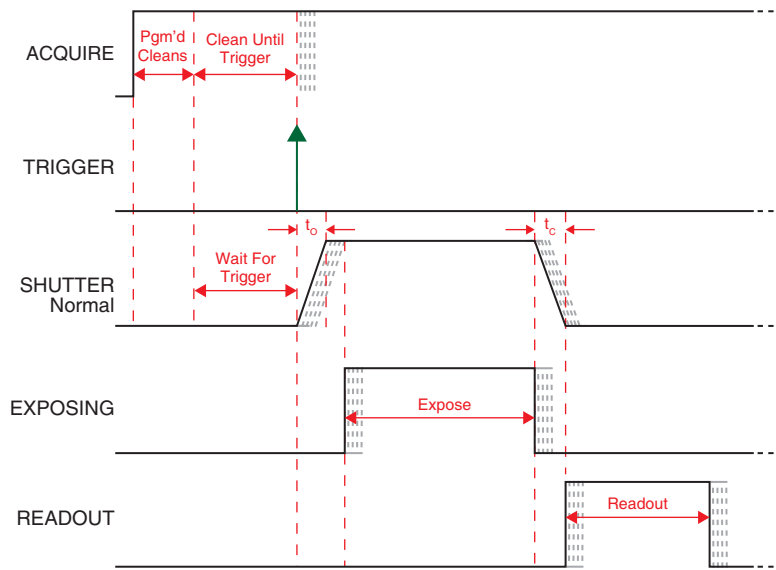


7.3.1.1 Normal Shutter Mode

When an incoming Trigger pulse has been received, cleaning of the array stops as soon as the current cleaning pattern has been completed and shifted. Because the incoming trigger is not synchronous with the cleaning cycle, there is an inherent jitter of up to one cleaning cycle in the system's response to an incoming trigger. After this, the shutter remains open for the programmed exposure time, and frame collection can begin.

Figure 7-3 illustrates the timing diagram for Clean Until Trigger, Normal shutter mode. In this figure, system jitter is shown as light gray dashed lines.

Figure 7-3: Timing Diagram: Clean Until Trigger, Normal Shutter Mode



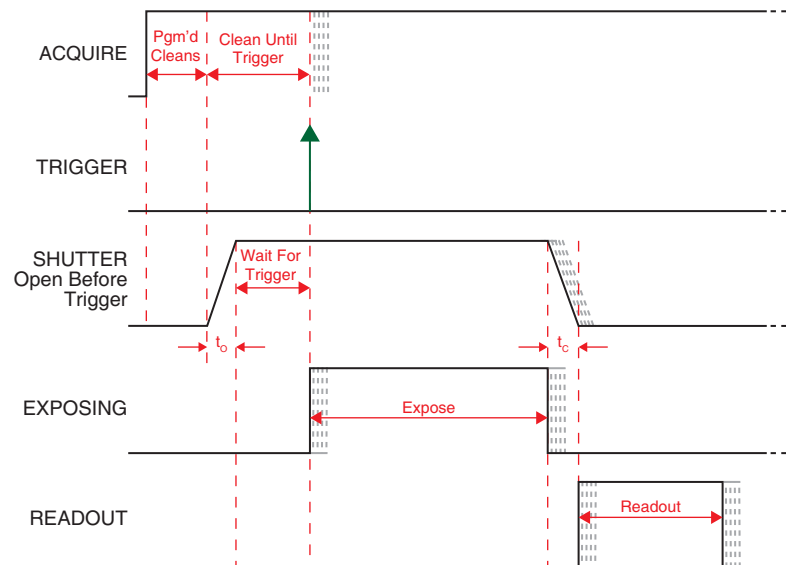
4411-0158_0027

7.3.1.2 Open Before Trigger Mode

With Open Before Trigger shutter mode, the shutter is opened at the beginning of Clean Until Trigger. As with Normal mode, once the incoming Trigger pulse has been received, cleaning of the array stops as soon as the current cleaning pattern has been completed and shifted. Because the incoming trigger is not synchronous with the cleaning cycle, there is an inherent jitter of up to one cleaning cycle in the system's response to an incoming trigger. After this, the shutter remains open for the programmed exposure time, and frame collection can begin.

Figure 7-4 illustrates the timing diagram for Clean Until Trigger, Open Before Trigger shutter mode. In this figure, system jitter is shown as light gray dashed lines.

Figure 7-4: Timing Diagram: Clean Until Trigger, Open Before Trigger



4411-0158_0006

If the vertical rows are shifted midway when the Trigger pulse arrives, the pulse is saved until the row shifting is completed, to prevent the CCD from getting out of step. As expected, the response latency is on the order of one vertical shift time, from 1-30 μs depending on the array. This latency does not prevent the incoming signal from being detected, since photo generated electrons are still collected over the entire active area. However, if the signal arrival is coincident with the vertical shifting, image smearing of up to one pixel is possible. The amount of smearing is a function of the signal duration compared to the single vertical shift time.

7.4 Saturation

When signal levels in some part of the image are very high, charge generated in one pixel may exceed the well capacity of the pixel, spilling over into adjacent pixels in a process called blooming. In this case a shorter exposure is advisable, with signal averaging to enhance S/N (Signal-to-Noise ratio) accomplished through the software.

For signal levels low enough to be readout-noise limited, longer exposure times, and therefore longer signal accumulation in the CCD, will improve the S/N ratio approximately linearly with the length of exposure time. However, due to cosmic ray strikes, the maximum practical exposure time is in the range of 15 to 30 minutes. Be aware that some deep depletion CCDs have a higher dark charge rate and may also be dark current limited.

Chapter 8: Analog to Digital Conversion

After the programmed exposure time has elapsed, accumulated charge stored in the CCD array must be:

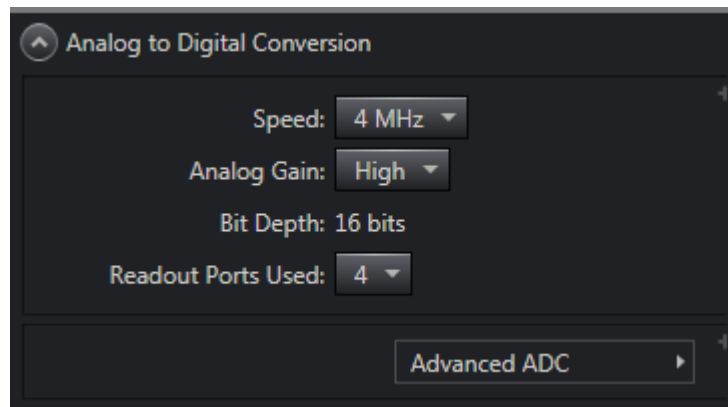
- Read out;
- Converted to a digital format;
- Transferred to the application software where it can be displayed and/or stored.

The number of ports used to read out data and other Analog-to Digital conversion factors are configured within LightField on the Analog to Digital Conversion expander using the following parameters:

- Readout Ports Used;
- Analog Gain;
- Speed.

See [Figure 8-1](#).

Figure 8-1: Typical Analog to Digital Conversion Expander



4411-0158_0062

The following sections describe the impact each of these parameters has on acquired image data.

8.1 Readout Ports Used

Readout begins by moving charge from the CCD image area to the shift register(s) in which each pixel typically has twice the capacity of each image pixel.

SOPHIA-XO is equipped with four output amplifiers/ports which provides flexibility in how acquired charge is read out. SOPHIA-XO can be programmed to use:

- 4 amplifiers/output ports;

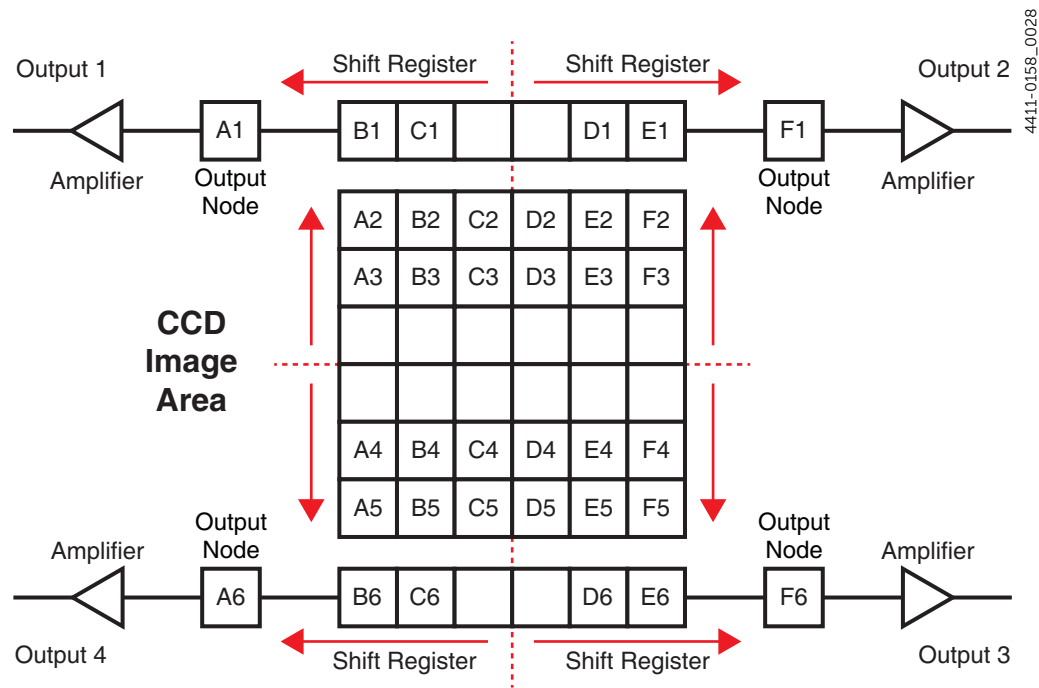


NOTE:

This is the recommended configuration as data readout is approximately four times faster with the same noise.

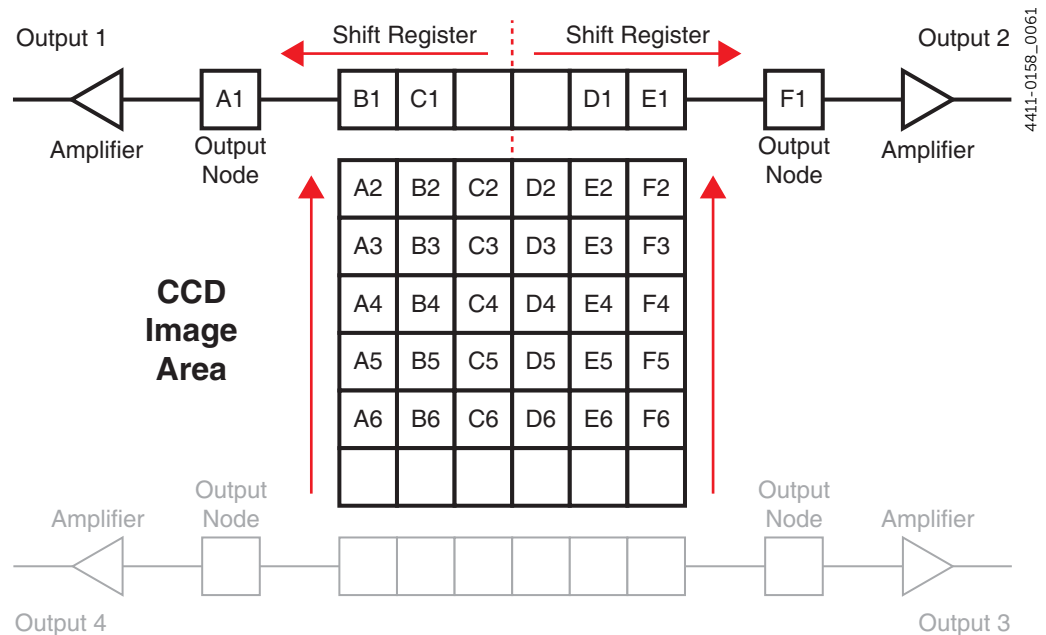
Figure 8-2 illustrates the charge being shifted and read out using four SOPHIA-XO output ports.

Figure 8-2: Data Readout Using Four Output Ports



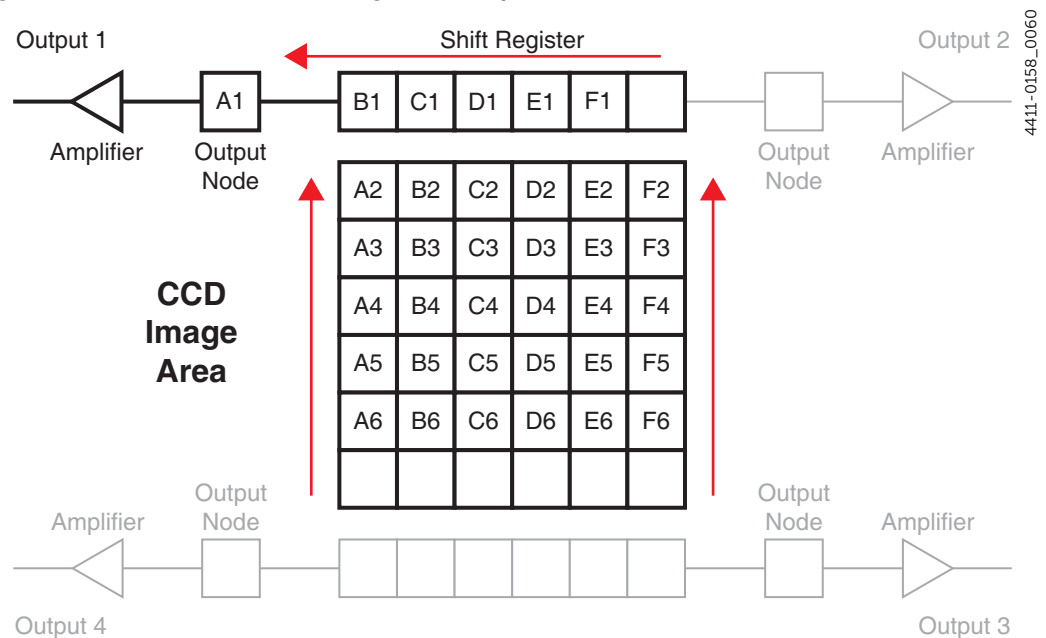
- 2 amplifiers/output ports;
Figure 8-3 illustrates the charge being shifted and read out using two SOPHIA-XO output ports.

Figure 8-3: Data Readout Using Two Output Ports



- 1 amplifier/output port.
Figure 8-4 illustrates the charge being shifted and read out using one SOPHIA-XO output port.

Figure 8-4: Data Readout Using One Output Port



Charge that has been stored in Shift Register pixels is shifted into the appropriate Output Node(s) and finally to the Output Amplifier where electrons are grouped as electrons/count.

8.1.1 Output Amplifier

Each Output Amplifier that has been configured for use amplifies the collected charge from the output node and transfers it to the ADC. The amount of Gain that is applied by each Output Amplifier is user configurable. Refer to [Section 8.3, Analog Gain](#), on page 54 for additional information.

8.2 Digitization

After gain has been applied to the signal, the Analog-to-Digital Converter (ADC) converts analog information (continuous amplitudes) into digital data (quantified, discrete steps,) that can be read, displayed, and stored by the application software. The number of bits per pixel is based on both the hardware and the settings configured into SOPHIA-XO using LightField.

Factors associated with digitization include:

- Speed
This is software configurable within LightField, and specifies the rate at which data are digitized.
- Baseline Offset.
This is not a user-configurable value; it is set at the factory at the time of manufacture.

These factors are discussed in the following paragraphs.

8.2.1 Speed

Because the readout noise for a CCD array increases with readout rate, it may be necessary at times to trade off readout speed for high dynamic range. SOPHIA-XO provides users flexibility regarding how quickly the data are digitized by supporting three user-configurable digitization rates:

- 100 kHz;
This should be used when the reduction of readout noise is critical to an experiment's success.
- 1 MHz;
- 4 MHz.
Provides the fastest possible data collection.

Switching between digitization speed can be completely controlled by software for total experiment automation.

8.2.2 ADC Offset (Bias)

With the camera's light path completely blocked, the CCD accumulates a dark charge pattern, dependent on the exposure time and camera temperature. The longer the exposure time and the warmer the camera, the larger this background will appear. To minimize the amount of this signal that gets digitized, the baseline has been offset by adding a voltage to the signal to bring the A/D output to a non-zero value, typically 550-600 counts. This offset value ensures that all the true variation in the signal can really be seen and not lost below the A/D "0" value. Since the offset is added to the signal, these counts only minimally reduce the range of the signal from 65535 (16-bit A/D) to a value in the range of 500-600 counts lower.



WARNING!

If a sudden change in the baseline signal is observed, there may be excessive humidity in the camera vacuum enclosure. Turn off the camera and contact Teledyne Princeton Instruments Customer Support. Refer to [Contact Information](#) on page 136 for complete information.

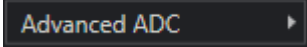


NOTES:

1. It is important to note that the bias level is not noise. It is a fully subtractable readout pattern. Every device has been thoroughly tested to ensure its compliance with Teledyne Princeton Instruments' demanding specifications.
2. The ADC Offset is pre-set at the factory and is not user-changeable.

8.2.2.1 Correct Pixel Bias

By default, Pixel Bias Correction is ENABLED in LightField. Correct Pixel Bias automatically corrects any pixel bias drift that may be introduced.

This setting can be disabled by clicking  on the Analog to Digital Conversion expander, and deselecting the Correct Pixel Bias option.

8.3 Analog Gain

Controller gain, a configurable function of the preamplifier, changes the relationship between the number of electrons acquired on the CCD and the Analog-to-Digital Units (ADUs) generated. The level of gain is configured by the Analog Gain parameter on the Analog to Digital Conversion expander.

Supported Analog Gain options are:

- **Low**
This gain setting is best suited for binning applications, particularly when high-level signals are being digitized. Although this setting may be used with non-binned modes, the CCD single pixel well typically will not reach ADC saturation when applying Low gain.
- **Medium**
This gain setting is typically selected for experiments within the mid-level intensity range.
- **High.**
Applications that consistently measure low-level signals should select this gain setting since it requires fewer electrons to generate each ADU. Additionally, this setting can reduce some sources of noise.

[Table 8-1](#) provides typical electron counts required to generate an ADU for each supported Analog Gain setting.



NOTE:

The Certificate of Performance included with SOPHIA-XO specifies the measured gain values for various Analog Gain settings.

Actual electron counts required are also dependent upon the configured readout rate.

Table 8-1: Typical Electron Counts vs. Analog Gain Setting

Low	Medium	High
5 e ⁻ /count	1.7 e ⁻ /count	0.7 e ⁻ /count

8.3.1 Example

In this example, it is assumed the incoming light level is identical in all three instances. The electron counts listed in [Table 8-1](#) are used to illustrate the relative effects of changing controller gain settings and may not reflect actual performance. Achievable gain depends on the CCD being used as well as the readout rate that has been configured.

- **Low**
Requires 5 electrons to generate one ADU.
Strong signals can be acquired without over-ranging the ADC array. If the gain is set to Low and the images or spectra appear weak, selecting Medium or High may improve results.
- **Medium**
Requires 1.7 electrons to generate one ADU.
When analog gain is set to Medium and images or spectra do not appear to utilize the full dynamic range of the ADC array, it may be worthwhile changing the gain setting to High.
However, if the ADC array appears to be saturated, changing the gain setting to Low is advised.
- **High**
Requires 0.7 electron to generate one ADU.
Some noise sources are reduced. Because fewer electrons are needed to generate an ADU, weaker signals can be more readily detected. Lower noise further enhances the ability to acquire weak signals.
If the ADC array appears to be saturated, changing the gain setting to Medium or Low is advised.

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Chapter 9: Full Frame Readout

When operating in Full Frame mode, SOPHIA-XO reads and processes a complete frame of data at a time via 1, 2, or 4 output ports. Every pixel of information is digitized individually.



REFERENCES:

Refer to [Section 8.1, Readout Ports Used](#), on page 50 for complete information about selecting the number of ports used.



NOTE:

For simplicity, this chapter describes a SOPHIA-XO system that has been configured to read out data using a single output port. Similar processes are employed when using 2 or 4 ports.

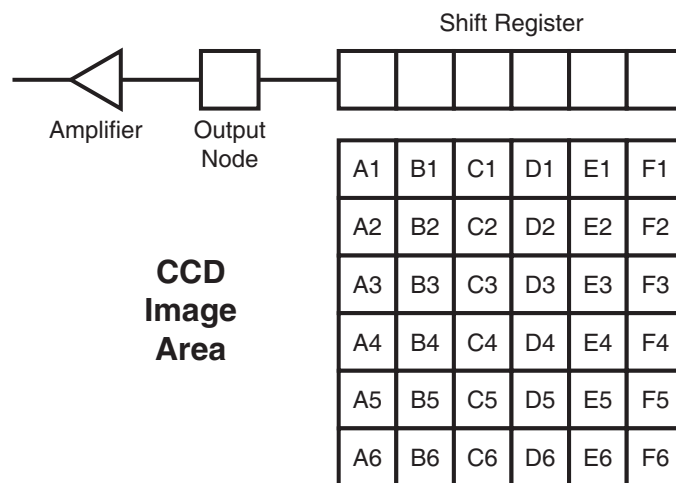
[Figure 9-1](#) illustrates a CCD array following exposure but prior to the beginning of readout.



NOTE:

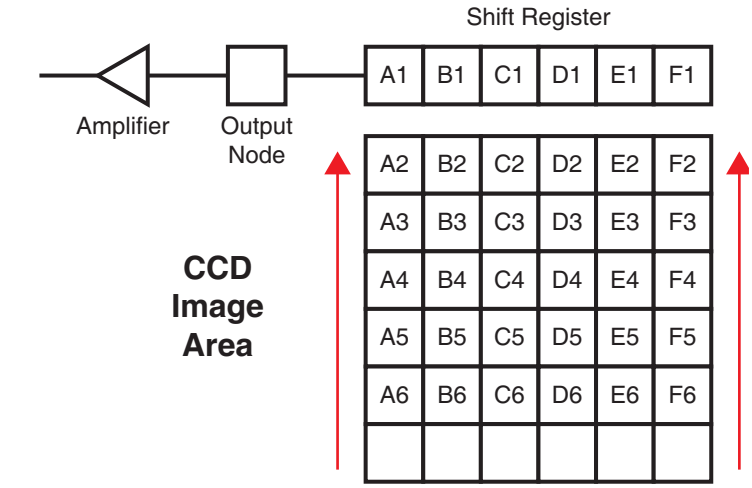
Capital letters represent different amounts of accumulated charge, both desired signal and dark charge.

Figure 9-1: Full Frame Readout: Unshifted CCD Charge



Readout of the CCD begins with the simultaneous shifting of all pixels one row toward the Shift Register which is a single row of pixels along the edge of the CCD. The Shift Register is not sensitive to light and is only used to store charge during readout. See [Figure 9-2](#).

Figure 9-2: Full Frame Readout: One Row of Charge Shifted into Shift Register



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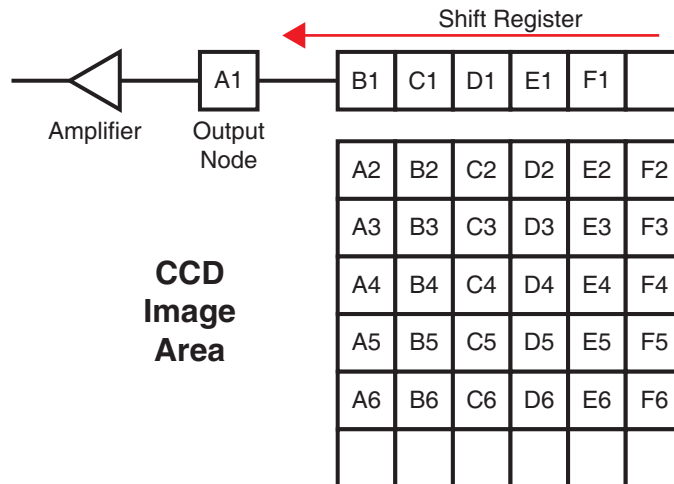


NOTE:

Typically, each pixel within the Shift Register can store up to twice as much charge as pixels within the CCD imaging area.

Once one row of charge has been shifted into the Shift Register, the charge is then shifted by one pixel toward the corresponding Output Node where it is then digitized. See [Figure 9-3](#).

Figure 9-3: Full Frame Readout: One Pixel of Charge Shifted to Output Node



4411-0158_0064

Once the charge within all of the Shift Register’s pixels has been shifted out and digitized, the next row of charge is shifted vertically into the shift register where it is then shifted, pixel by pixel into the Output Node and digitized. This process continues until all accumulated charge in the CCD has been shifted out and digitized. The result is zero charge stored within each CCD pixel and the array is immediately ready for the next exposure.

9.1 Calculating Image Acquisition/Readout Time

The total time required to acquire and readout a full frame of data at full resolution is calculated as follows:

$$(1) \quad t_{FF} = t_R + t_{exp} + t_c$$

where:

- t_R is the CCD readout time;
Refer to [Section 9.1.1, CCD Readout Time](#), for additional information.
- t_{exp} is the exposure time;
This is a user-defined value, and is configured in LightField on the Common Acquisition Setting expander.
- t_c is the sum of the shutter opening and closing compensation times.
Refer to [Section A.6, Shutter Specifications](#), on page 110 for complete specifications.

9.1.1 CCD Readout Time

LightField automatically calculates the readout time, including Region of Interest (ROI) operations and an approximation of overhead times.



NOTE:

When SOPHIA-XO is configured for either 2- or 4-port readout, LightField accounts for very specific symmetry rules regarding ROI dimensions and placement.

CCD readout time is approximately calculated as follows:

$$(2) \quad t_R = (N_y \times t_i) + (N_y \times N_x \times t_{pix})$$

where:

- t_R is the readout time;
- N_y is the number of rows within the CCD;
When SOPHIA-XO is configured for 4-port readout:
 $N_y = \frac{1}{2}$ [total number of CCD rows]
For example, if a CCD is 2048 rows high, $N_y = 1024$.
- N_x is the number of columns within the CCD;
When SOPHIA-XO is configured for 2-port or 4-port readout:
 $N_x = \frac{1}{2}$ [total number of CCD columns]
For example, if a CCD is 2048 columns wide, $N_x = 1024$.

- t_i is the time needed to shift one line into the shift register.
- t_{pix} is the time needed to process one pixel.

**NOTE:**

Equation 2 above does not include certain overhead times. A more accurate calculation of CCD Readout Time is provided by LightField.

A subsection of the CCD can be read out at full resolution, sometimes dramatically increasing the readout rate while retaining the highest resolution in the region of interest (ROI). To approximate the readout rate of an ROI, in Equation 2 substitute the x and y dimensions of the ROI in place of the dimensions of the full CCD. Some overhead time, however, is required to read out and discard the unwanted pixels.

9.2 Experiment Timing

For many experiments, the acquisition of quality/useful data is dependent on precise synchronization with external experiment events. Using the SYNC input on the rear of SOPHIA-XO, externally-generated trigger pulses can be used to control:

- Shutter operation;

**REFERENCES:**

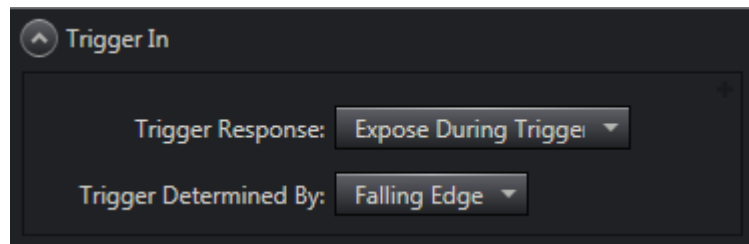
Refer to [Chapter 12, Shutter Configuration and Control](#), on page 101 for detailed information about each available shutter mode.

- Data readout.

This section describes how to configure SOPHIA-XO to use incoming trigger pulses to precisely control experiment synchronization in Full Frame mode.

[Figure 9-4](#) illustrates a typical Trigger In expander.

Figure 9-4: Trigger In Expander



Depending on the specific experiment, two parameters are used to configure SOPHIA-XO's response to an incoming trigger pulse:

- [Trigger Response](#);
- [Trigger Determined By](#).

Information about the configuration and use of each of these parameters is described in the following sections.

9.2.1 Trigger Response

The Trigger Response parameter defines how, upon receipt of an incoming trigger pulse, SOPHIA-XO reads out data that have been acquired.

Supported Trigger Response modes are:

- [No Response](#);
- [Start on Single Trigger](#);
- [Readout Per Trigger](#);
- [Expose During Trigger Pulse](#).

The following sections describe each of these options and how experiment synchronization is impacted. Within the following sections, the following symbols may be used:

- t_{exp} = exposure time;
- t_{O} = shutter opening delay;
- t_{C} = shutter closing delay;
- t_{R} = data readout time.

9.2.1.1 No Response

When No Response is selected, incoming trigger pulses are ignored. This mode is typically used for experiments incorporating a constant light source (e.g., a CW laser, DC lamp.) Other experiments that can use this mode are high repetition studies where the number of light impulses occurring during a single shutter cycle is so large that the light source appears to be a continuously illuminated source.

Supported Shutter modes are:

- [Normal](#);
- [Always Closed](#);
- [Always Open](#).

The following sections describe how each of these modes impacts experiment timing.



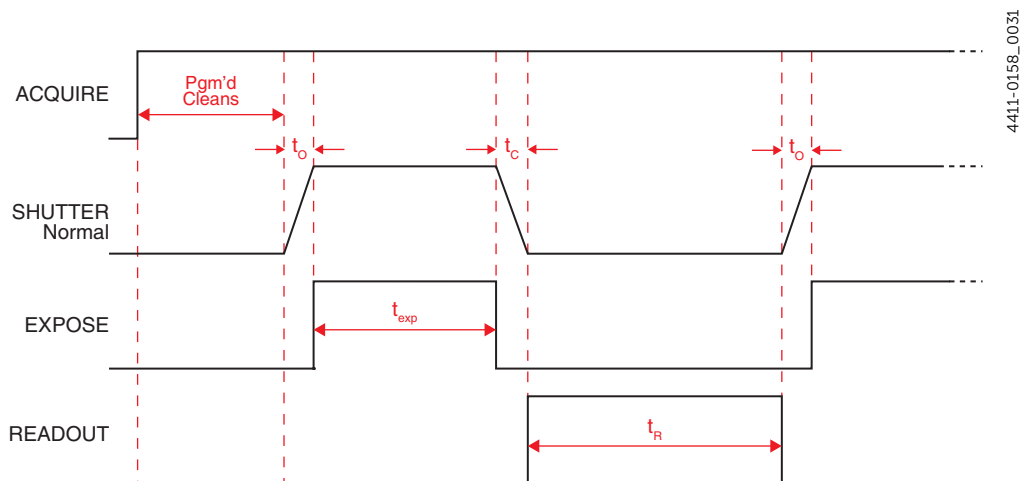
NOTE:

In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

9.2.1.1.1 Normal

Figure 9-5 illustrates the timing diagram for No Response mode combined with Normal shutter mode.

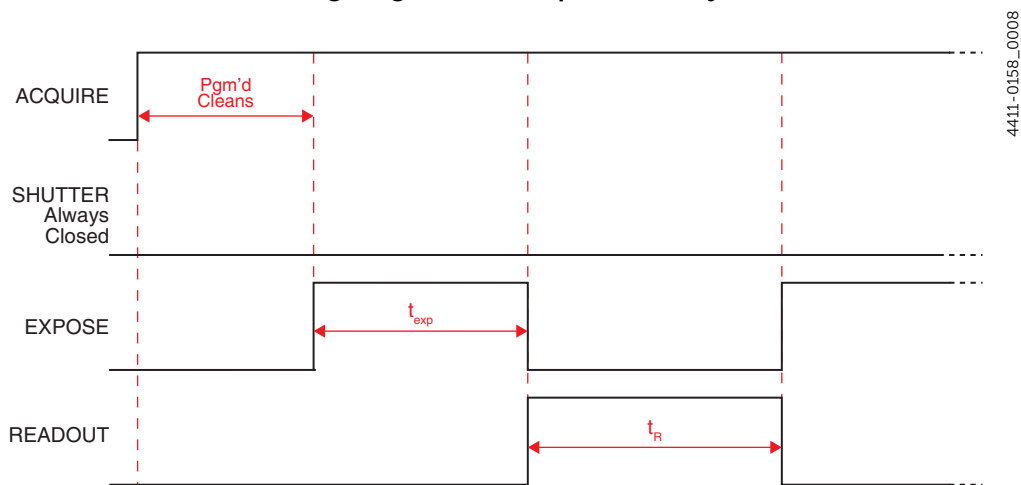
Figure 9-5: Full Frame Timing Diagram: No Response, Normal



9.2.1.1.2 Always Closed

Figure 9-6 illustrates the timing diagram for No Response mode combined with Always Closed shutter mode.

Figure 9-6: Full Frame Timing Diagram: No Response, Always Closed

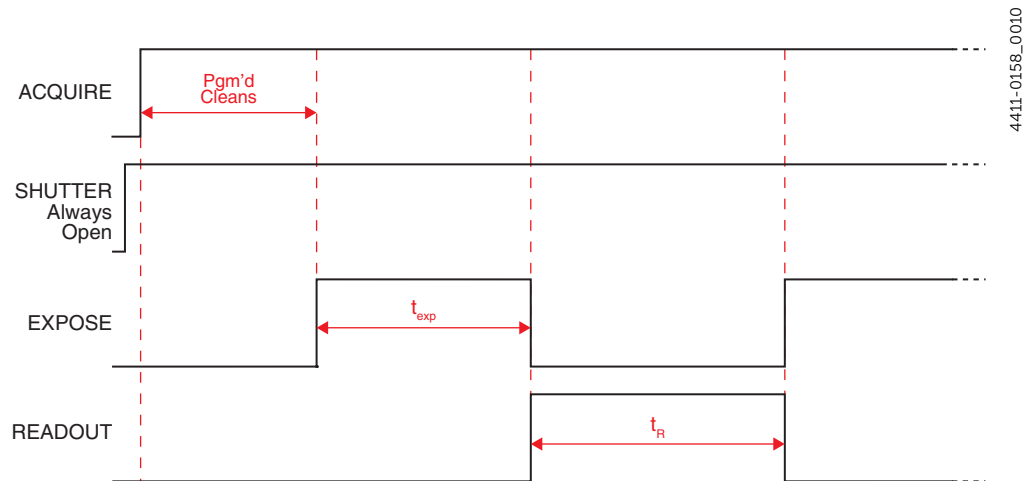


This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that a dark reference file is often unnecessary.

9.2.1.1.3 Always Open

Figure 9-7 illustrates the timing diagram for No Response mode combined with Always Open shutter mode.

Figure 9-7: Full Frame Timing Diagram: No Response, Always Open



This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.)

9.2.1.2 Start on Single Trigger

Begins the experiment when the trigger is received and the system executes all programmed events.

Supported Shutter modes are:

- Normal;
- Always Closed;
- Always Open;
- Open Before Trigger.

The following sections describe how each of these modes impacts experiment timing.



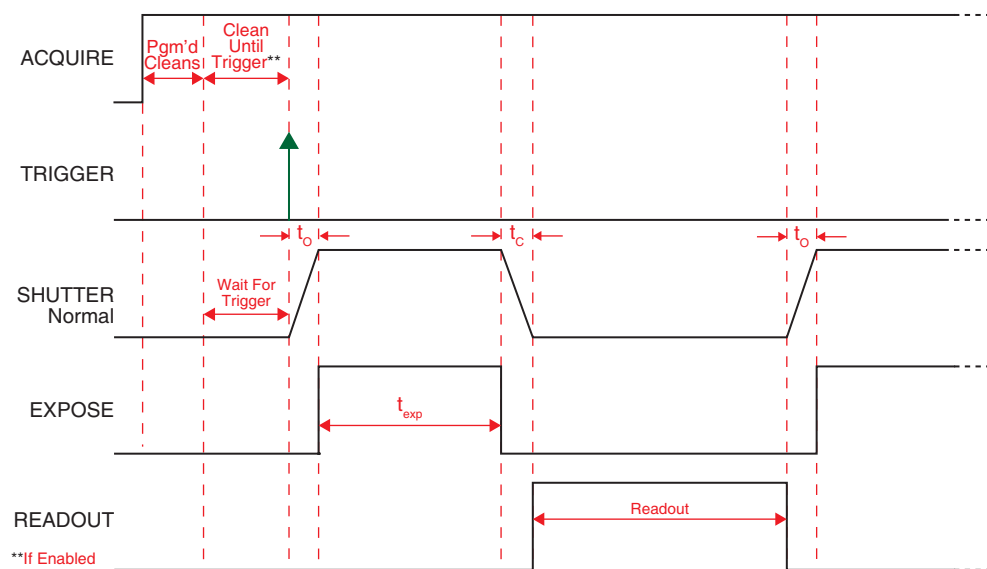
NOTES:

1. When Clean Until Trigger is enabled, an inherent jitter is introduced into the system Refer to [Section 7.3.1, Clean Until Trigger](#), on page 45 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

9.2.1.2.1 Normal

[Figure 9-8](#) illustrates the timing diagram for Start on Single Trigger mode combined with Normal shutter mode.

Figure 9-8: Full Frame Timing Diagram: Start on Single Trigger, Normal

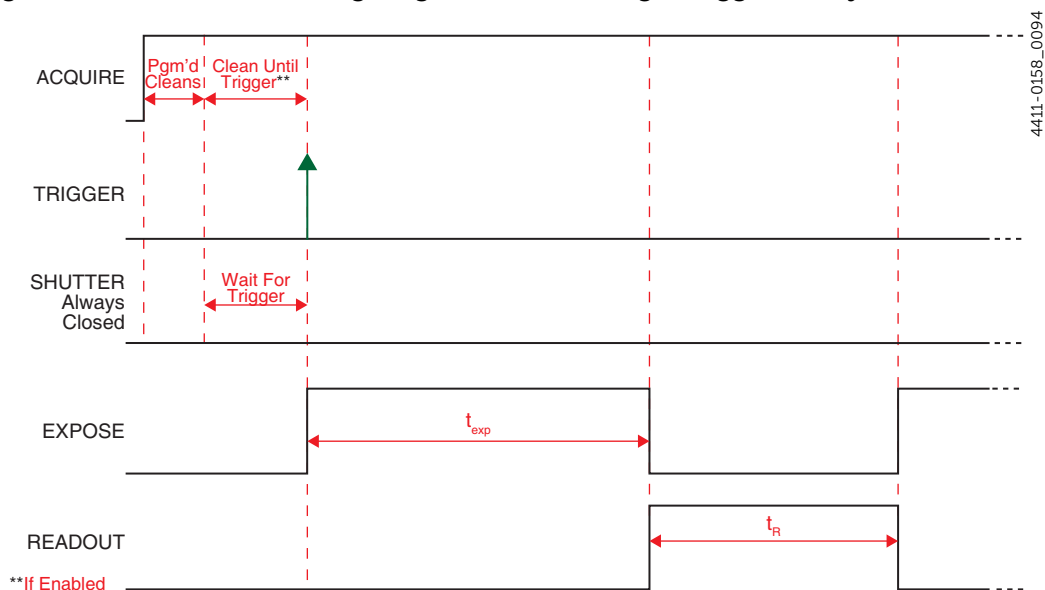


**If Enabled

9.2.1.2.2 Always Closed

Figure 9-9 illustrates the timing diagram for Start on Single Trigger mode combined with Always Closed shutter mode.

Figure 9-9: Full Frame Timing Diagram: Start on Single Trigger, Always Closed

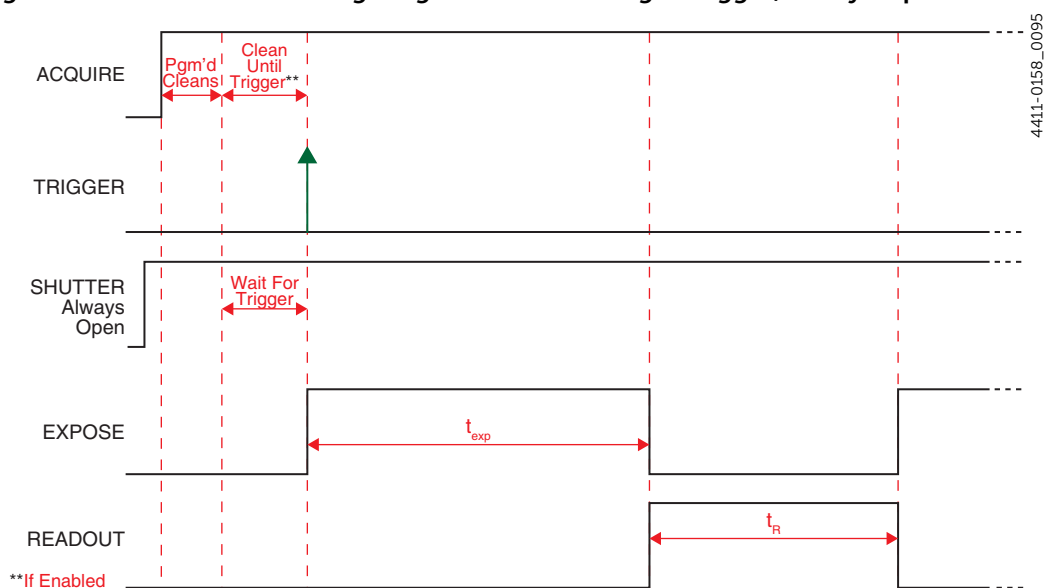


This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that a dark reference file is often unnecessary.

9.2.1.2.3 Always Open

Figure 9-10 illustrates the timing diagram for Start on Single Trigger mode combined with Always Open shutter mode.

Figure 9-10: Full Frame Timing Diagram: Start on Single Trigger, Always Open

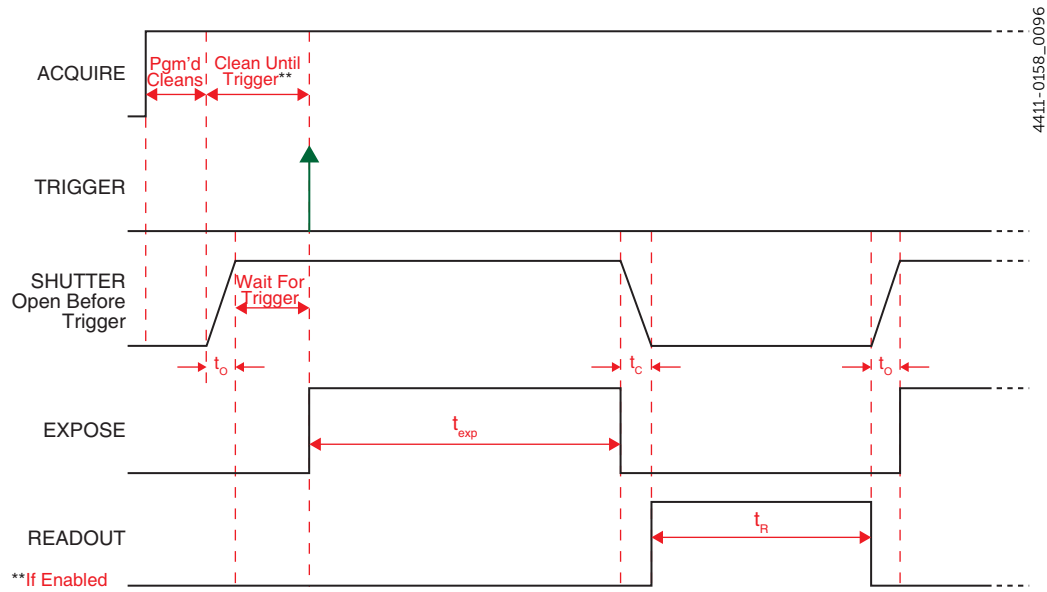


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.)

9.2.1.2.4 Open Before Trigger

Figure 9-11 illustrates the timing diagram for Start On Single Trigger mode combined with Open Before Trigger shutter mode.

Figure 9-11: Full Frame Timing Diagram: Start on Single Trigger, Open Before Trigger



9.2.1.3 Readout Per Trigger

With Readout Per Trigger, all exposures are synchronized with an incoming trigger pulse. Synchronization occurs on either the Rising Edge or Falling Edge of the trigger pulse which is configured using the Trigger Determined By parameter on the Trigger In expander. Refer to [Section 9.2.2, Trigger Determined By](#), on page 74 for complete information.

Supported Shutter modes are:

- Normal;
- Always Closed;
- Always Open;
- Open Before Trigger.

The effect each of these shutter modes has on experiment synchronization is described in the following sections.



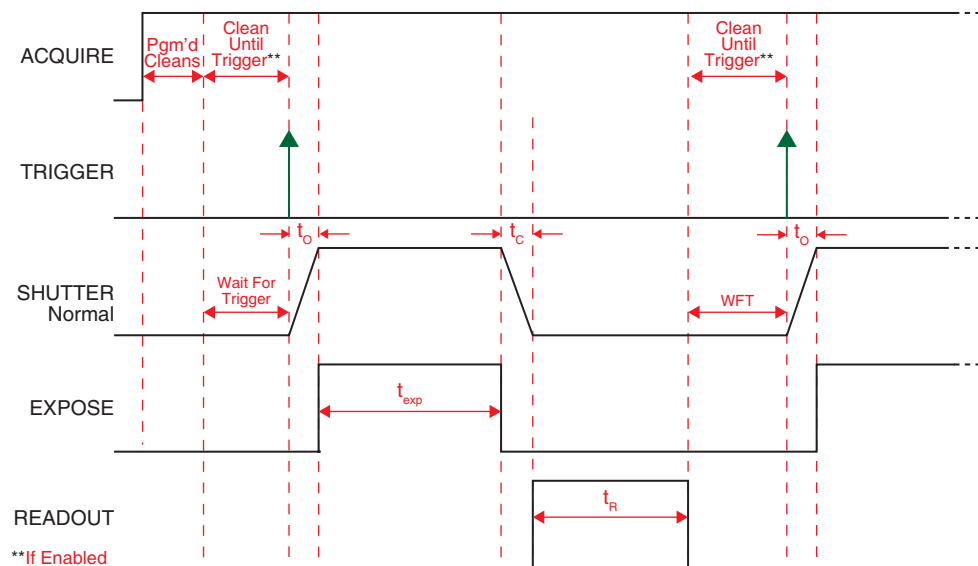
NOTES:

1. When Clean Until Trigger is enabled, an inherent jitter is introduced into the system. Refer to [Section 7.3.1, Clean Until Trigger](#), on page 45 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

9.2.1.3.1 Normal

[Figure 9-12](#) illustrates the timing diagram for Readout Per Trigger mode combined with Normal shutter mode.

Figure 9-12: Full Frame Timing Diagram: Readout Per Trigger, Normal



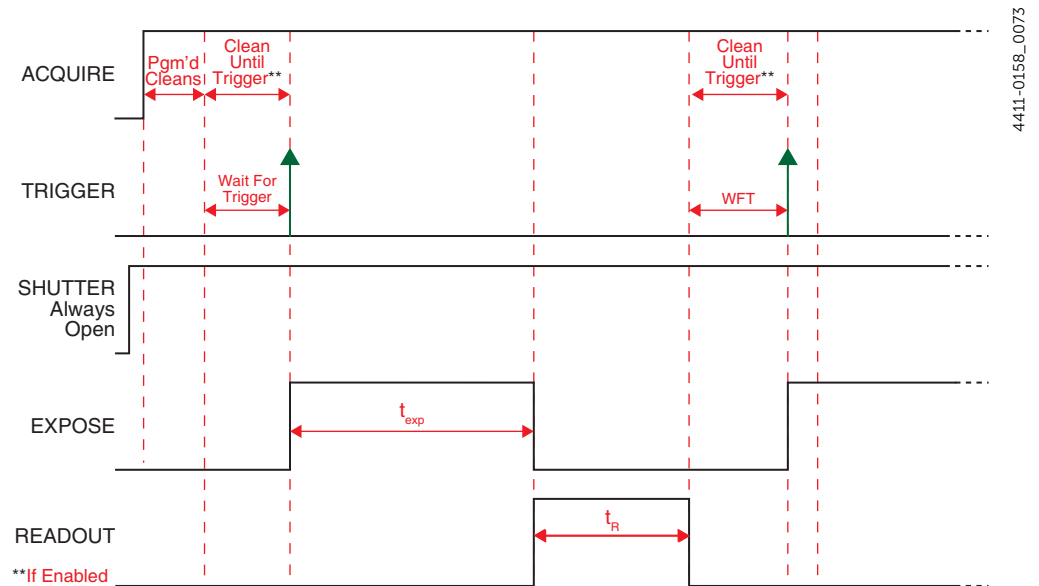
When a trigger pulse has been received, SOPHIA-XO opens the active shutter for the programmed exposure time, t_{exp} .

Once the exposure is complete, the shutter is closed, and the CCD array is read out.

9.2.1.3.3 Always Open

Figure 9-14 illustrates the timing diagram for Readout Per Trigger mode combined with Always Open shutter mode.

Figure 9-14: Full Frame Timing Diagram: Readout Per Trigger, Always Open

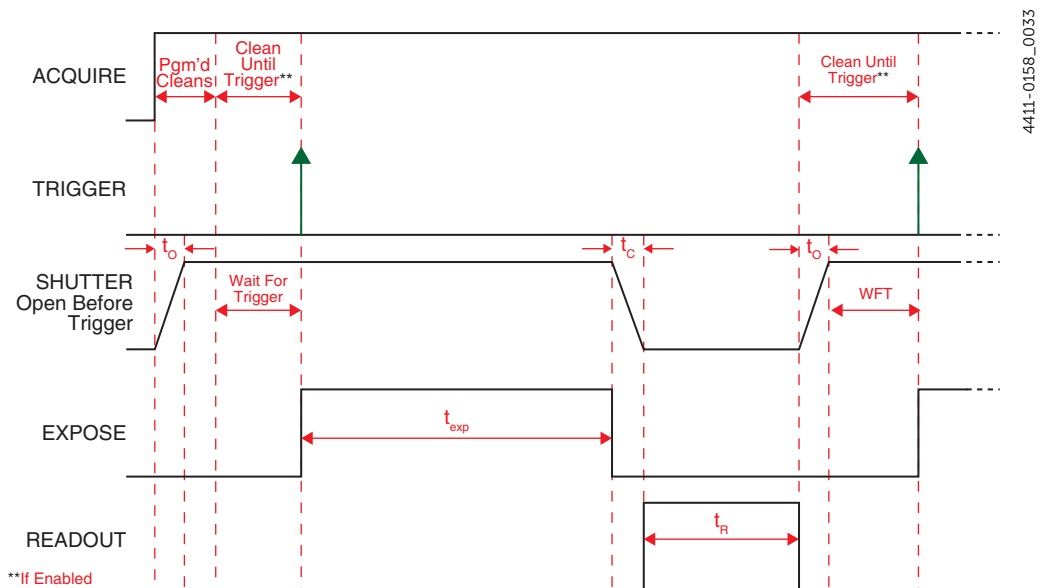


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) [Open Before Trigger](#) is closely related.

9.2.1.3.4 Open Before Trigger

Figure 9-15 illustrates the timing diagram for Readout Per Trigger mode combined with Open Before Trigger shutter mode.

Figure 9-15: Full Frame Timing Diagram: Readout Per Trigger, Open Before Trigger



When Open Before Trigger is selected, the active shutter is partially synchronized with the experiment.

Upon arrival of the first trigger pulse at the SYNC connector, the shutter:

- Remains open for the configured exposure period;
- Closes;
- The CCD is read out.

Once data readout is complete, the active shutter reopens and waits for the next frame.

Open Before Trigger is most useful when the time between the trigger pulse and the desired incoming signal is not sufficiently long enough to allow the active shutter to completely open.

Unfortunately, this mode exposes the CCD to ambient light while the shutter is open between frames. If the ambient light is constant, triggers occur at regular intervals, and continuous cleaning is enabled, then, depending on the specific cleaning pattern used, most of the average background light can be removed, except for noise attributed to jitter (refer to [Section 7.3.1, Clean Until Trigger](#), on page 45.) If a short cleaning pattern is used, not all ambient light will be removed since only a portion of the CCD will be cleaned on each pattern, and the result is a blurry residual.

Additionally, shot noise of the background cannot be subtracted which may be significant. Consider applications using High gain (i.e., $1e^-/ADU$), and ambient equals 10% of full scale (i.e., $6500 e^-$.) The shot noise is then approximately 80 ADU, which is significantly greater than the camera's read noise.

As with Normal shutter mode, accurate background subtraction may not be possible for the first frame.

In addition to signal from ambient light, dark charge accumulates during the wait time. Any variation in the external sync frequency also affects the amount of dark charge, even if light is not falling on the CCD during this time.

9.2.1.4 Expose During Trigger Pulse

Controls when exposure begins and ends.

Supported Shutter modes are:

- Normal;
- Always Closed;
- Always Open;
- Open Before Trigger.

The effect each of these shutter modes has on experiment synchronization is described in the following sections. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.



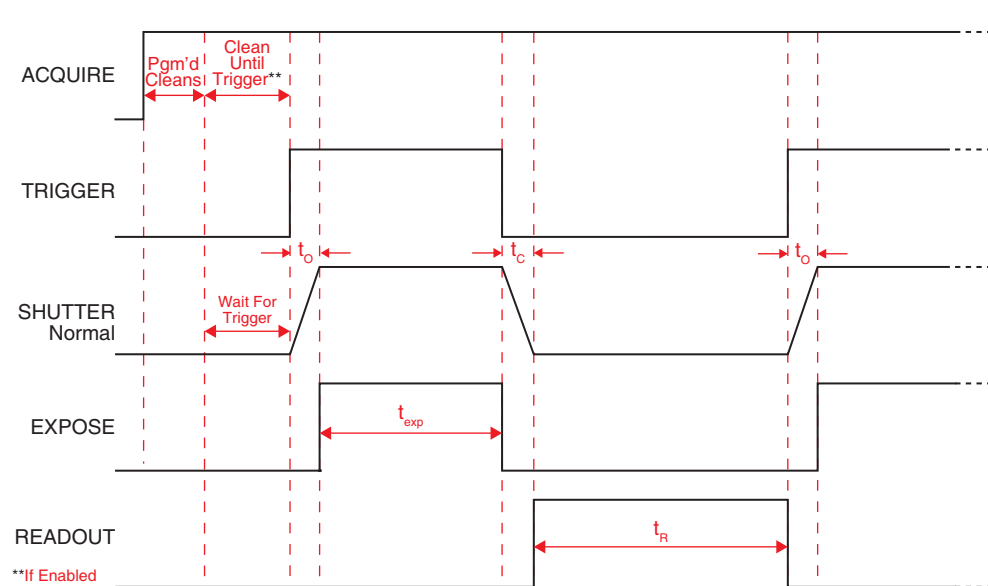
NOTES:

1. When Clean Until Trigger is enabled, an inherent jitter is introduced into the system Refer to [Section 7.3.1, Clean Until Trigger](#), on page 45 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

9.2.1.4.1 Normal

[Figure 9-16](#) illustrates the timing diagram for Expose During Trigger mode combined with Normal shutter mode.

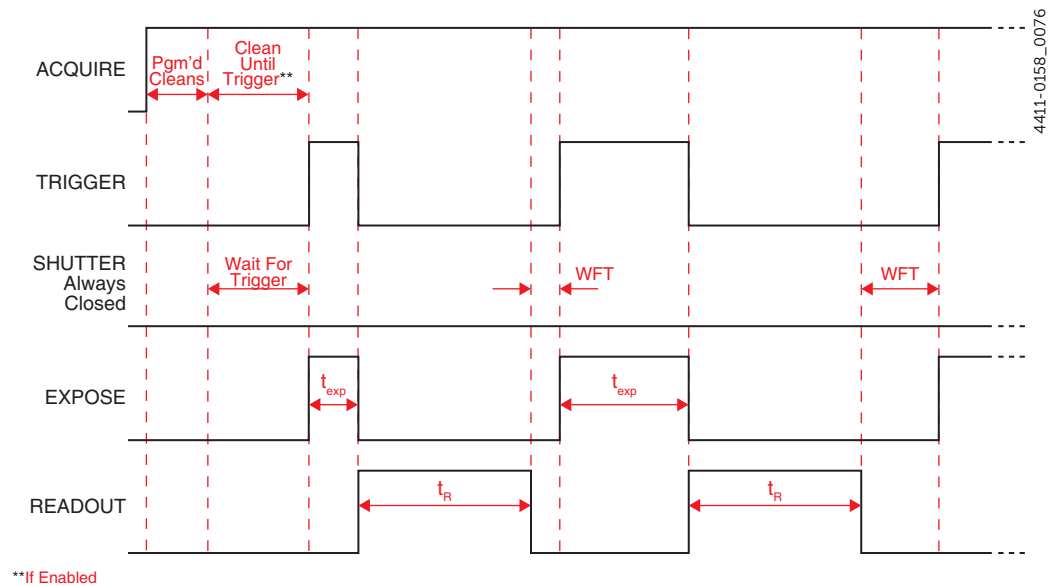
Figure 9-16: Full Frame Timing Diagram: Expose During Trigger, Normal



9.2.1.4.2 Always Closed

Figure 9-17 illustrates the timing diagram for Expose During Trigger Pulse mode combined with Always Closed shutter mode.

Figure 9-17: Timing Diagram: Expose During Trigger, Always Closed

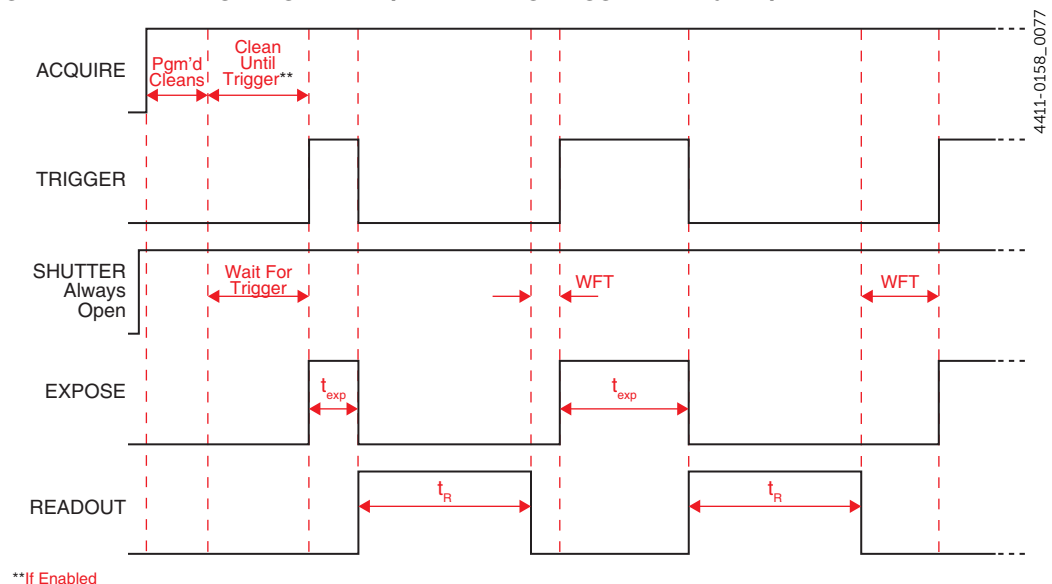


This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that the dark reference file is typically unnecessary.

9.2.1.4.3 Always Open

Figure 9-18 illustrates the timing diagram for Expose During Trigger Pulse mode combined with Always Open shutter mode.

Figure 9-18: Timing Diagram: Expose During Trigger, Always Open

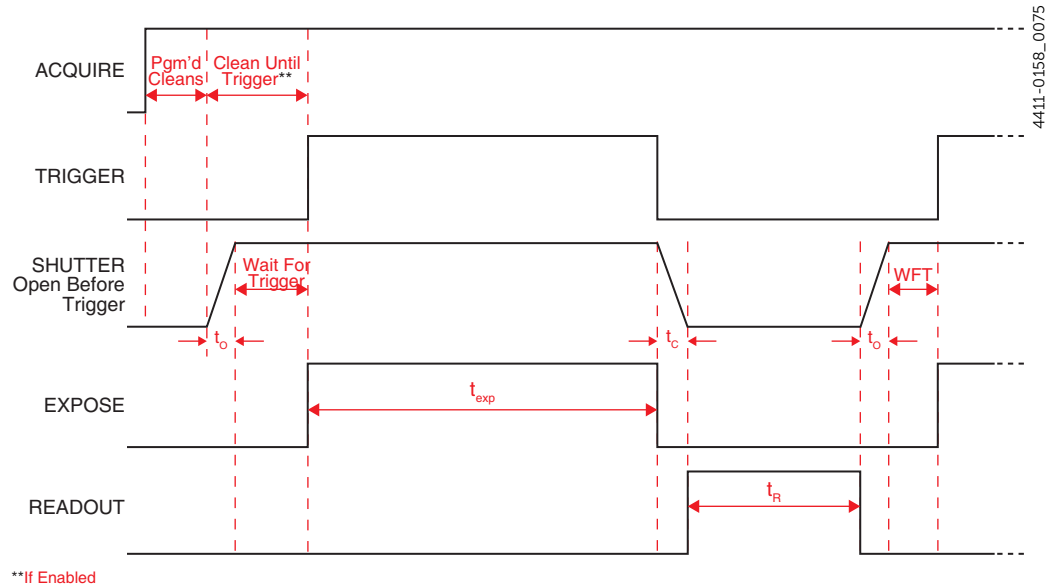


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) [Open Before Trigger](#) is closely related.

9.2.1.4.4 Open Before Trigger

Figure 9-19 illustrates the timing diagram for Expose During Trigger Pulse mode combined with Open Before Trigger shutter mode.

Figure 9-19: Timing Diagram: Expose During Trigger, Open Before Trigger



9.2.2 Trigger Determined By

When using an external trigger to initiate a readout, SOPHIA-XO can be configured to respond to:

- The rising edge of the incoming trigger pulse;
- The falling edge of the incoming trigger pulse.

The Trigger Determined By parameter configures this behavior. Valid values are:

- Rising Edge;

SOPHIA-XO responds to the rising edge of incoming trigger pulses. Depending on the specific system configuration, one or more subsequent trigger pulses may be required (or ignored) by the system. Refer to [Section 9.2.1, Trigger Response](#), on page 61 for complete information about configuring incoming trigger responses.

When using [Expose During Trigger Pulse](#) mode:

- Exposure begins on the Rising Edge of each incoming trigger pulse;
- Exposure ends on the Falling Edge of the respective trigger pulse.

The timing diagrams in [Section 9.2.1.4, Expose During Trigger Pulse](#), on page 71 illustrate this.



NOTE:

If SOPHIA-XO is busy when a subsequent trigger pulse is received, the trigger is ignored.

- Falling Edge

SOPHIA-XO responds to the falling edge of incoming trigger pulses. Depending on the specific system configuration, one or more subsequent trigger pulses may be required (or ignored) by the system. Refer to [Section 9.2.1, Trigger Response](#), on page 61 for complete information about configuring incoming trigger responses.

When using [Expose During Trigger Pulse](#) mode:

- Exposure begins on the Falling Edge of each incoming trigger pulse;
- Exposure ends on the Rising Edge of the respective trigger pulse.



NOTE:

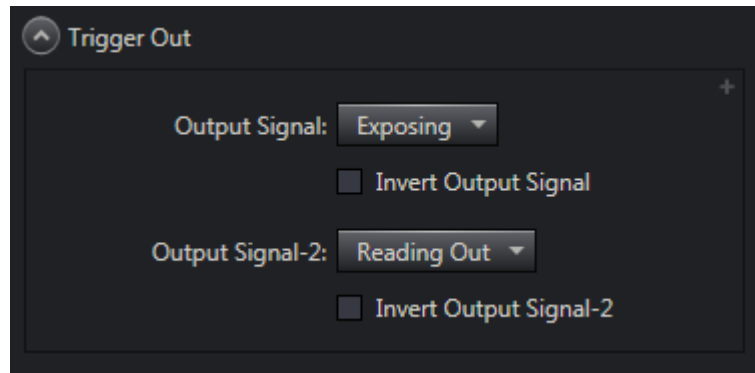
If SOPHIA-XO is busy when a subsequent trigger pulse is received, the trigger is ignored.

9.3 Trigger Out

In addition to being able to synchronize SOPHIA-XO with an experiment, additional equipment can be synchronized using the Trigger Out connector on the rear of SOPHIA-XO.

Two trigger out pulses are configured on the Trigger Out expander, shown in [Figure 9-20](#).

Figure 9-20: Typical Trigger Out Expander



4411-0158_0034

The following options are available for each of the two output signals:

- Acquiring;
The associated output signal is high when SOPHIA-XO is acquiring or ready to receive the first trigger.
- Always High;
The associated output signal is always high.
- Exposing;
The associated output signal is high when the sensor is exposed as configured within LightField.
- Reading Out;
The associated output signal when data are being read out of the sensor.
- Shifting Under Mask;
This option is not currently supported by SOPHIA-XO cameras.
When using Kinetics Readout (refer to [Chapter 10, Kinetics Readout](#), on page 77,) this output indicates when Kinetics shifts are occurring.
- Shutter Open;
The associated output signal is high when the shutter is open.
- Waiting for Trigger.
The associated output signal when SOPHIA-XO is waiting for an incoming trigger.

Each of these options can also be inverted to create active low signals using the Invert Output Signal option.

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Chapter 10: Kinetics Readout

Kinetics mode uses the CCD to expose and store a limited number of images in rapid succession. The time it takes to shift each line (or row) on a CCD is typically within the range of a few hundred nanoseconds to few microseconds, depending on the CCD. For SOPHIA-XO, this shift can be achieved in as little as 24 μ s. Kinetics mode allows full frame CCDs to take time-resolved images. Optical or mechanical masking of the array is required.

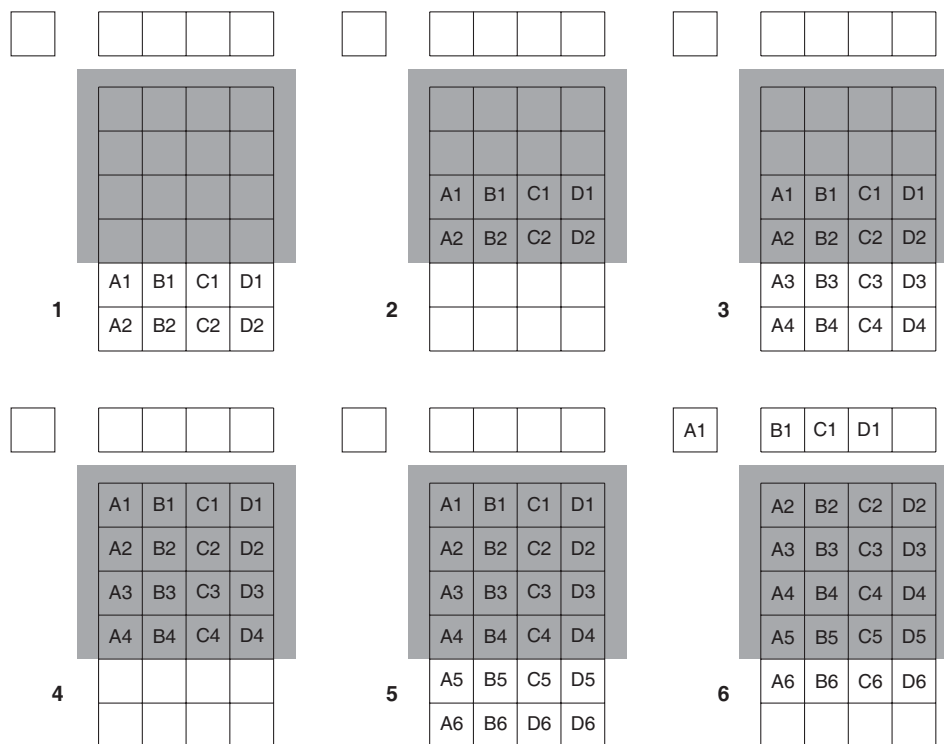


NOTE:

Because SOPHIA-XO supports 1-, 2-, or 4-port data readout, Kinetics can be very complicated. However, LightField handles Kinetics operation automatically, and following each Kinetics shift, data readout via the selected port(s) occurs seamlessly.

Figure 10-1 illustrates Kinetics readout for a 4 x 6 CCD configured for 1-port readout. In this example, 2/3 of the array is masked, either mechanically or optically. The shutter opens to expose a 4 x 2 region. While the shutter remains open, charge is quickly shifted just under the mask, and the exposure is repeated. After a third image is collected the shutter is closed and the CCD is read out. Since the CCD can be read out slowly, very high dynamic range is achieved. Shifting and readout are portrayed Figure 10-1.

Figure 10-1: 1-Port Kinetics Readout

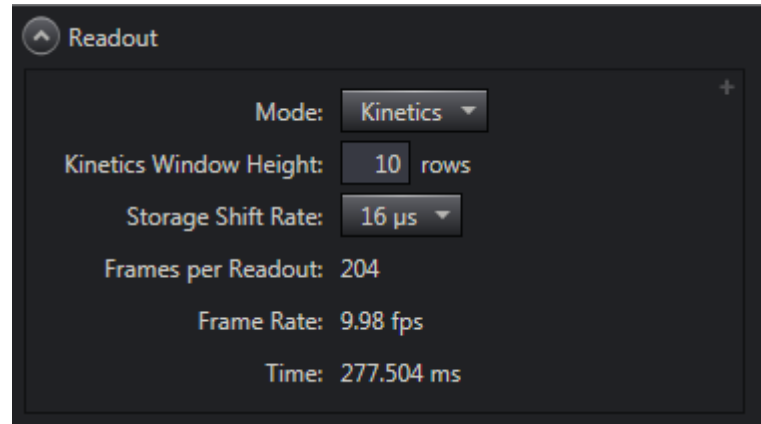


4411-0158_035

10.1 Kinetics Mode Parameters

Kinetics mode is selected and configured on the Readout expander as shown in [Figure 10-2](#).

Figure 10-2: Typical Readout Expander: Kinetics Mode Parameters



4411-0158_0036

10.1.1 Kinetics Window Height

Defines the height, in rows, of the unmasked area of the CCD to be used for kinetics. Valid values are [1 ... 1024] rows, inclusive, in 1 row increments.

10.1.2 Storage Shift Rate

Defines the length of time required, in microseconds, to shift one row of acquired data into the sensor storage area.

Valid values are:

- 24 μs;
- 32 μs;
- 48 μs;
- 80 μs.

10.1.3 Frames per Readout

This is a calculated value that is dependent on the configured values for:

- Kinetics Window Height
- Storage Shift Rate

10.1.4 Frame Rate

This is a calculated value that is dependent on the configured values for:

- Kinetics Window Height
- Storage Shift Rate

10.2 Experiment Timing

For many experiments, the acquisition of quality/useful data is dependent on precise synchronization with external experiment events. Using the SYNC input on the rear of SOPHIA-XO, externally-generated trigger pulses can be used to control:

- Shutter Operation;



REFERENCES:

Refer to [Chapter 12, Shutter Configuration and Control](#), on page 101 for detailed information about each available shutter mode.



CAUTION!

Although NORMAL Shutter mode is available in Kinetics Readout, programming a SOPHIA-XO for NORMAL mode when using Kinetics is **strongly discouraged**. This combination will result in high shutter repetition rates and short exposure times which may permanently damage/destroy the shutter.

Shutters are not covered by the warranty.

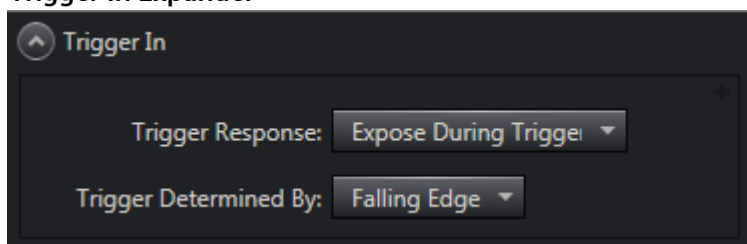
If an application requires both NORMAL shutter mode and Kinetics Readout, contact Teledyne Princeton Instruments for assistance prior to attempting this configuration. Refer to [Contact Information](#) on page 136 for complete information.

- Data Readout.

This section describes how to configure SOPHIA-XO to use incoming trigger pulses to precisely control experiment synchronization in Kinetics mode.

[Figure 10-3](#) illustrates a typical Trigger In expander.

Figure 10-3: Trigger In Expander



Depending on the specific experiment, two parameters are used to configure SOPHIA-XO's response to an incoming trigger pulse:

- [Trigger Response](#);
- [Trigger Determined By](#).

The following sections describe each of these options and how experiment synchronization is impacted. Within the following sections, the following symbols may be used:

- t_{exp} = exposure time;
- t_{O} = shutter opening delay;
- t_{C} = shutter closing delay;
- t_{R} = data readout time.

10.2.1 Trigger Response

The Trigger Response parameter defines how SOPHIA-XO responds upon receipt of an incoming trigger pulse.

Supported Trigger Response modes are:

- [No Response](#);
- [Start on Single Trigger](#);
- [Readout Per Trigger](#);
- [Shift Per Trigger](#);
- [Expose During Trigger Pulse](#);

The following sections describe each of these trigger modes and how experiment synchronization is impacted based on the selected Shutter Mode.



NOTE:

Throughout the remainder of this section, for all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.1 No Response

When No Response is selected, any incoming trigger pulses are ignored.

In this mode, SOPHIA-XO acquires a series of images, each with the Exposure Time that has been configured on the Common Acquisition Settings expander. The time between successive image frames may be as short as 24 μs and is limited by the time required to shift an image under the mask.

The time between successive image frames is calculated by multiplying the configured [Storage Shift Rate](#) (in ns/row) by the configured [Kinetics Window Height](#) in rows. The exact number of frames depends on the selected [Kinetics Window Height](#) and is equal to the number of pixels perpendicular to the shift register divided by the Window Size.



NOTE:

LightField displays only the integer result of this division in the Frames per Readout field.

Two integrate signals (Exposing) are provided on the LOGIC OUT connector for timing measurements. These signals are configured on the [Trigger Out](#) expander, and are named Output Signal and Output Signal-2.

Referring back to the example presented in [Figure 10-1](#):

- Six pixels are perpendicular to the shift register;
- The [Kinetics Window Height](#) is two pixels;
- The number of frames is 3.

When [Storage Shift Rate](#) rate is configured to 24 $\mu\text{s}/\text{row}$, the Shift time is 48 μs per frame. If the shift rate is increased to 80 $\mu\text{s}/\text{row}$, the Shift time increases to 160 μs per frame.

Supported Shutter modes are:

- [Normal](#);
- [Always Closed](#);
- [Always Open](#).

The following sections describe how each of these modes impacts experiment timing.

10.2.1.1.1 Normal

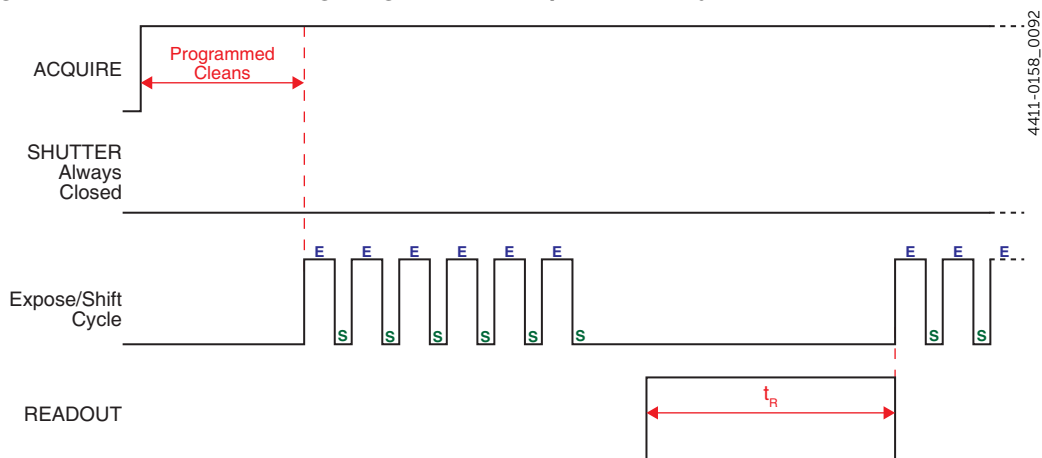
**CAUTION!**

The use of this mode is **strongly discouraged**. Contact Teledyne Princeton Instruments for assistance before implementing this mode. Refer to [Contact Information](#) on page 136 for complete information.

10.2.1.1.2 Always Closed

[Figure 10-4](#) illustrates the timing diagram for No Response mode combined with Always Closed shutter mode.

Figure 10-4: Kinetics Timing Diagram: No Response, Always Closed

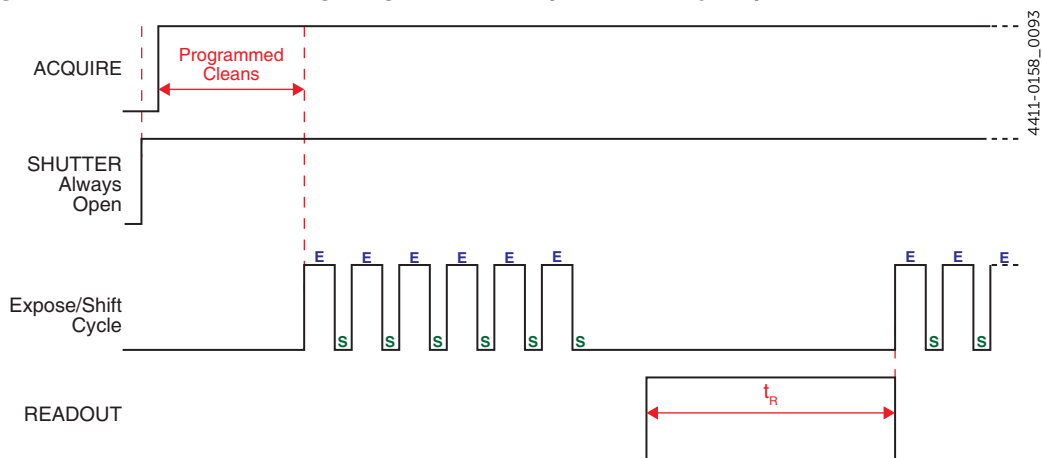


This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that a dark reference file is often unnecessary.

10.2.1.1.3 Always Open

[Figure 10-5](#) illustrates the timing diagram for No Response mode combined with Always Open shutter mode.

Figure 10-5: Kinetics Timing Diagram: No Response, Always Open



This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.)

10.2.1.2 Start on Single Trigger

Begins the experiment when the trigger is received.

One single incoming trigger causes the system to execute all programmed events, such as, but not limited to:

- Kinetics Exposures;
- Shifts;
- Readout;
- etc.

Supported Shutter modes are:

- [Normal](#);
- [Always Closed](#);
- [Always Open](#);
- [Open Before Trigger](#).

The following sections describe how each of these modes impacts experiment timing.



NOTES:

1. When Clean Until Trigger is enabled, an inherent jitter is introduced into the system Refer to [Section 7.3.1, Clean Until Trigger](#), on page 45 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.2.1 Normal



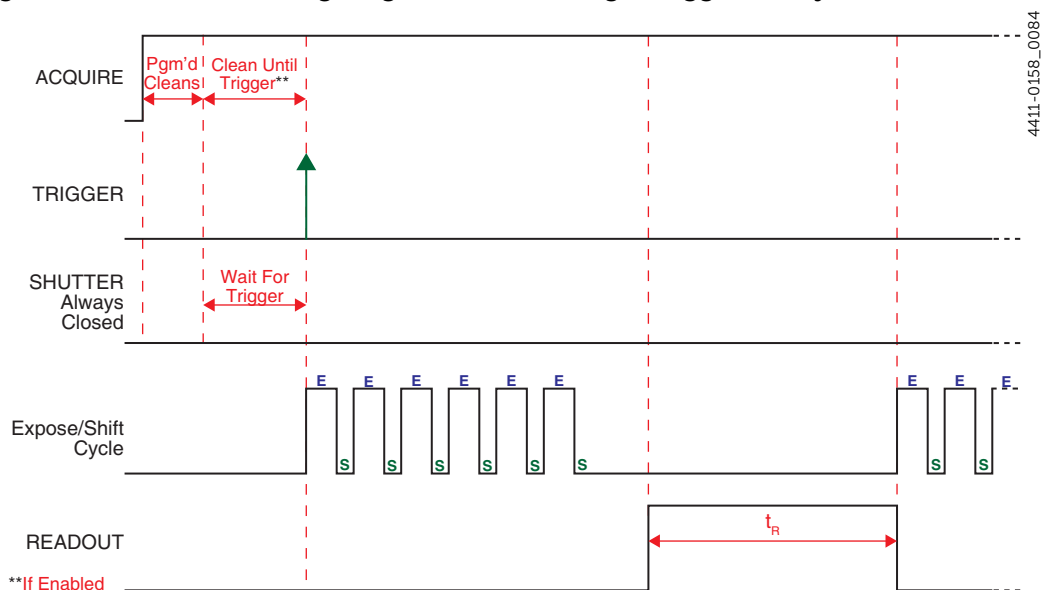
CAUTION!

The use of this mode is **strongly discouraged**. Contact Teledyne Princeton Instruments for assistance before implementing this mode. Refer to [Contact Information](#) on page 136 for complete information.

10.2.1.2.2 Always Closed

Figure 10-4 illustrates the timing diagram for Start on Single Trigger mode combined with Always Closed shutter mode.

Figure 10-6: Kinetics Timing Diagram: Start on Single Trigger, Always Closed

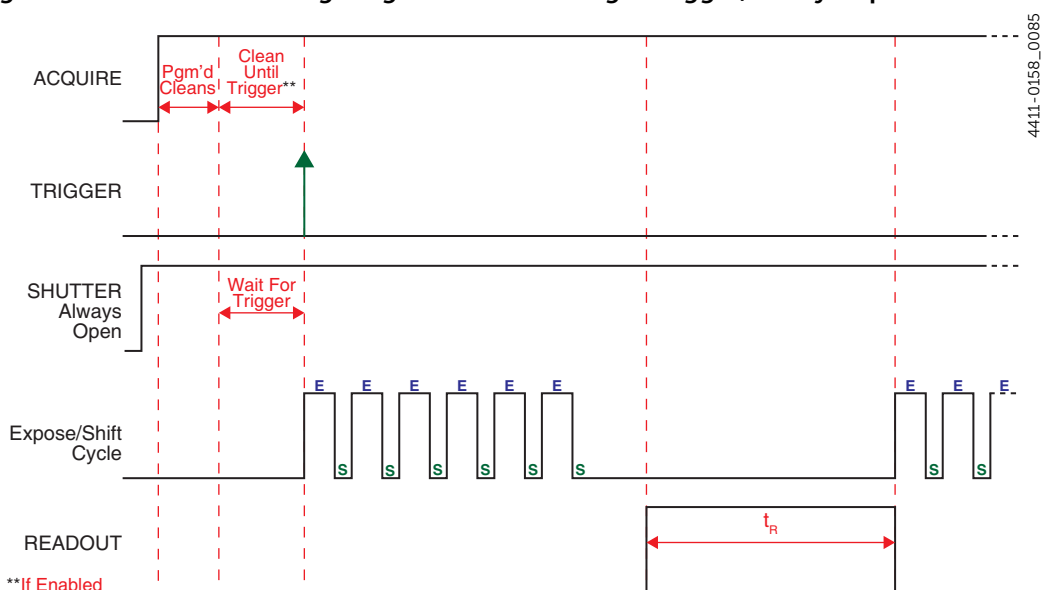


This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that a dark reference file is often unnecessary.

10.2.1.2.3 Always Open

Figure 10-5 illustrates the timing diagram for Start on Single Trigger mode combined with Always Open shutter mode.

Figure 10-7: Kinetics Timing Diagram: Start on Single Trigger, Always Open

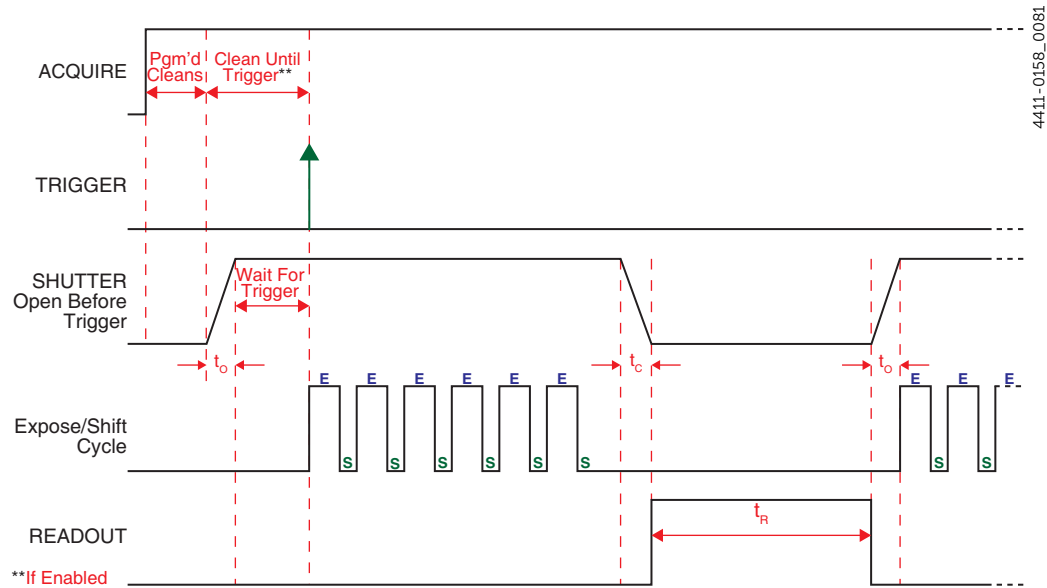


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.)

10.2.1.2.4 Open Before Trigger

Figure 10-8 illustrates the timing diagram for Start On Single Trigger mode combined with Open Before Trigger shutter mode.

Figure 10-8: Kinetics Timing Diagram: Start On Single Trigger, Open Before Trigger



**If Enabled

10.2.1.3 Readout Per Trigger

When configured for Readout Per Trigger, SOPHIA-XO requires one trigger to initiate an entire series of exposure-shift cycles (e.g., one External Trigger pulse initiates the collection of six frames).

When Acquire or Run is selected:

- The active shutter is opened;
- SOPHIA-XO acquires data using the configured Exposure Time;
- An external trigger is applied to the SYNC connector on the rear of SOPHIA-XO.

After a series of images has been acquired, the active shutter closes and the CCD is read out at normal speeds. Once readout is complete, SOPHIA-XO is ready for the next series of exposures.

Supported Shutter modes are:

- [Normal](#);
- [Always Closed](#);
- [Always Open](#);
- [Open Before Trigger](#).

The following sections describe how each of these modes impacts experiment timing.



NOTES:

1. When Clean Until Trigger is enabled, an inherent jitter is introduced into the system. Refer to [Section 7.3.1, Clean Until Trigger](#), on page 45 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.3.1 Normal



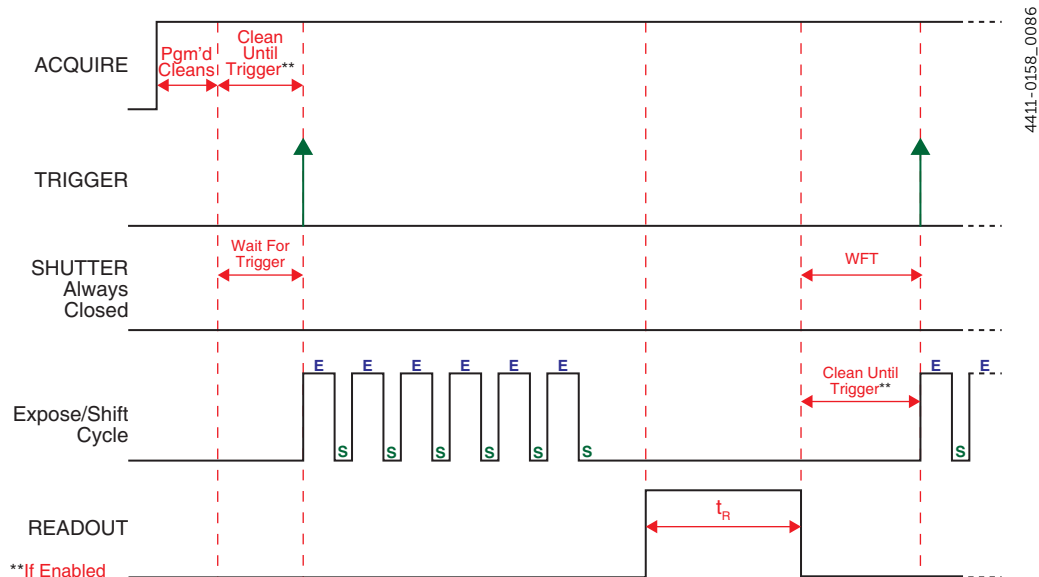
CAUTION!

The use of this mode is **strongly discouraged**. Contact Teledyne Princeton Instruments for assistance before using this shutter mode. Refer to [Contact Information](#) on page 136 for complete information.

10.2.1.3.2 Always Closed

Figure 10-15 illustrates the timing diagram for Readout Per Trigger mode combined with Always Closed shutter mode.

Figure 10-9: Kinetics Timing Diagram: Readout Per Trigger, Always Closed



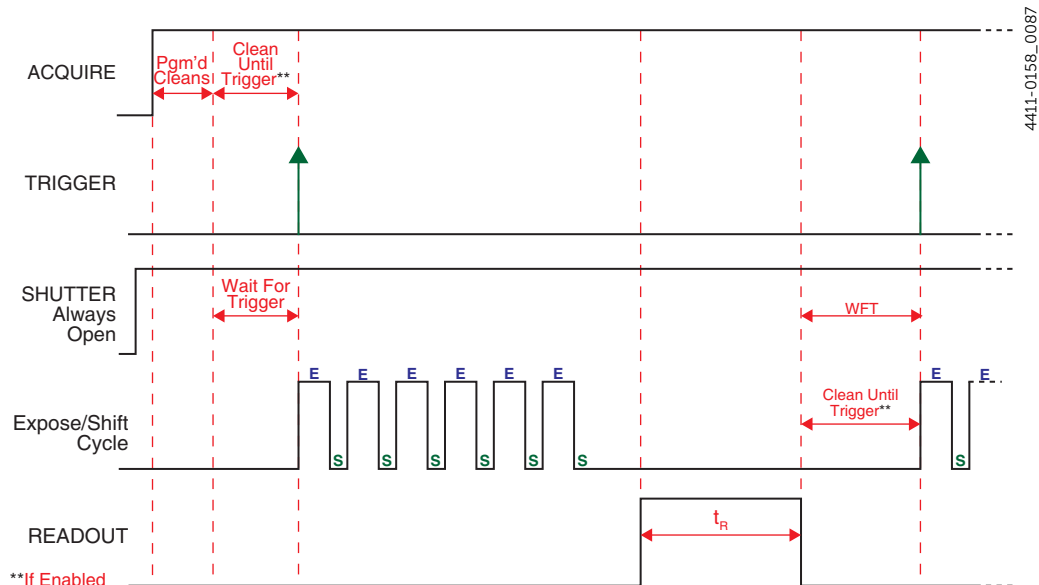
4411-0158_0086

This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that a dark reference file is often unnecessary.

10.2.1.3.3 Always Open

Figure 10-16 illustrates the timing diagram for Readout Per Trigger Pulse mode combined with Always Open shutter mode.

Figure 10-10: Kinetics Timing Diagram: Readout Per Trigger, Always Open



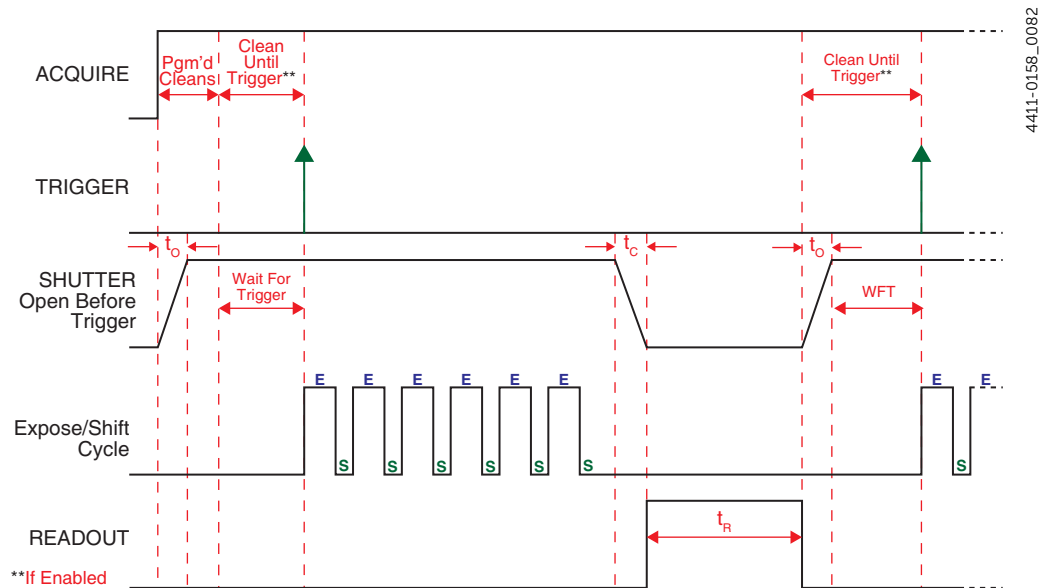
4411-0158_0087

This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) **Open Before Trigger** is closely related.

10.2.1.3.4 Open Before Trigger

Figure 10-17 illustrates the timing diagram for Readout Per Trigger mode combined with Open Before Trigger shutter mode.

Figure 10-11: Kinetics Timing Diagram: Readout Per Trigger, Open Before Trigger



10.2.1.4 Shift Per Trigger

When configured for Shift Per Trigger, SOPHIA-XO's active shutter opens when Acquire or Run is clicked. Each exposure-shift cycle throughout the acquisition is triggered independently by a an incoming Trigger Pulse applied at the SYNC connector.

Shift Per Trigger is useful when each subframe must be synchronized with a pulsed external light source such as a laser. Once the series is complete, the active shutter closes and readout begins. Since the shutter is open during the entire series of images, irregularly spaced external pulses will result in exposures of different lengths. Once the series has been read out, the camera is ready for the next series.

Supported Shutter modes are:

- [Normal](#);
- [Always Closed](#);
- [Always Open](#);
- [Open Before Trigger](#).

The following sections describe how each of these modes impacts experiment timing.



NOTES:

1. When Clean Until Trigger is enabled, an inherent jitter is introduced into the system Refer to [Section 7.3.1, Clean Until Trigger](#), on page 45 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.4.1 Normal



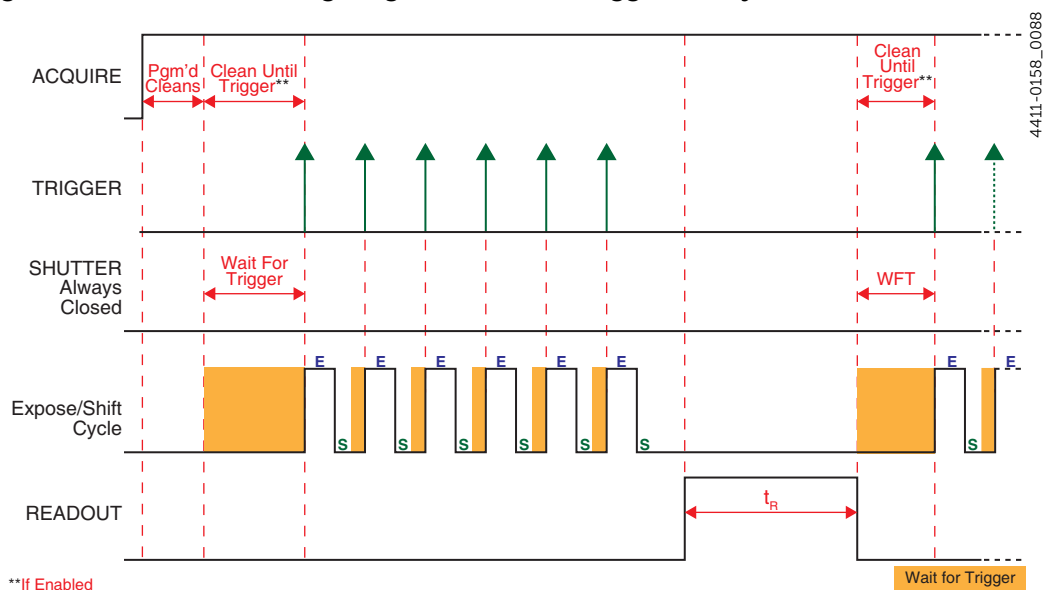
CAUTION!

The use of this mode is **strongly discouraged**. Contact Teledyne Princeton Instruments for assistance before using this shutter mode. Refer to [Contact Information](#) on page 136 for complete information.

10.2.1.4.2 Always Closed

Figure 10-15 illustrates the timing diagram for Shift Per Trigger mode combined with Always Closed shutter mode.

Figure 10-12: Kinetics Timing Diagram: Shift Per Trigger, Always Closed

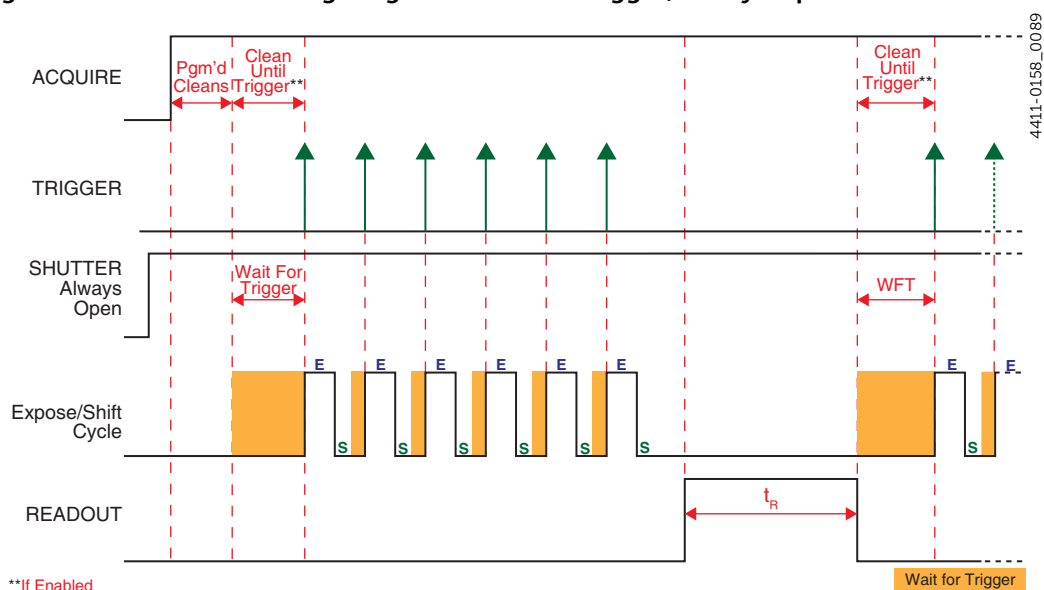


This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that a dark reference file is often unnecessary.

10.2.1.4.3 Always Open

Figure 10-16 illustrates the timing diagram for Shift Per Trigger mode combined with Always Open shutter mode.

Figure 10-13: Kinetics Timing Diagram: Shift Per Trigger, Always Open

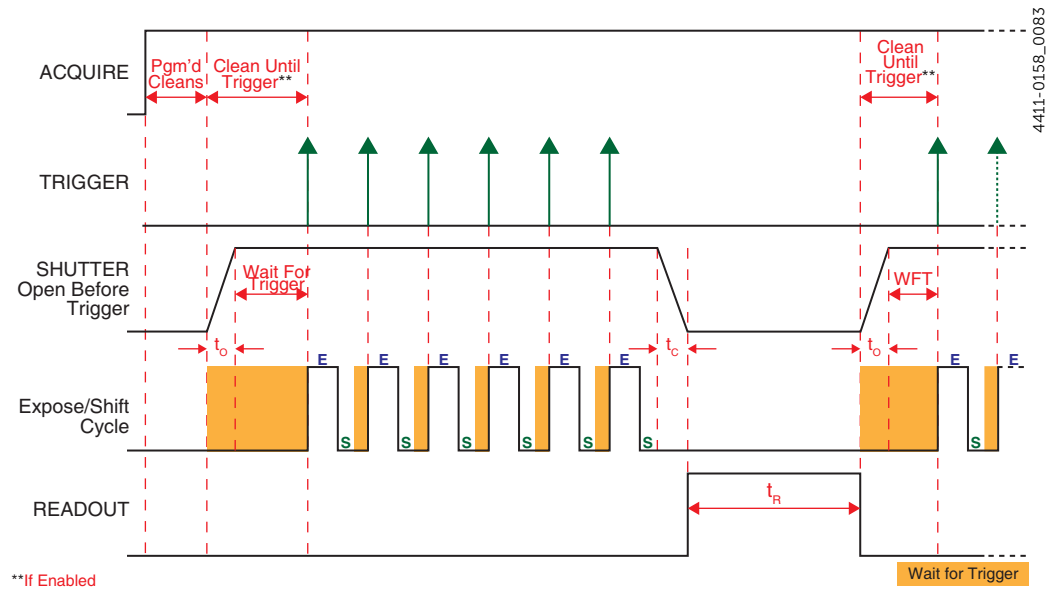


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) **Open Before Trigger** is closely related.

10.2.1.4.4 Open Before Trigger

Figure 10-17 illustrates the timing diagram for Shift Per Trigger mode combined with Open Before Trigger shutter mode.

Figure 10-14: Kinetics Timing Diagram: Shift Per Trigger, Open Before Trigger



10.2.1.5 Expose During Trigger Pulse

When configured for Expose During Trigger Pulse, CCD exposure is controlled by the rising and falling edges of the incoming trigger pulse.

- The shutter begins opening on the leading edge of the incoming trigger pulse;
- The shutter begins closing on the falling edge of the incoming trigger pulse.

In this mode, both Shutter Opening and Shutter Closing times must be included in timing calculations.

Supported Shutter modes are:

- [Normal](#);
- [Always Closed](#);
- [Always Open](#);
- [Open Before Trigger](#).

The following sections describe how each of these modes impacts experiment timing.



NOTES:

1. When Clean Until Trigger is enabled, an inherent jitter is introduced into the system. Refer to [Section 7.3.1, Clean Until Trigger](#), on page 45 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.5.1 Normal



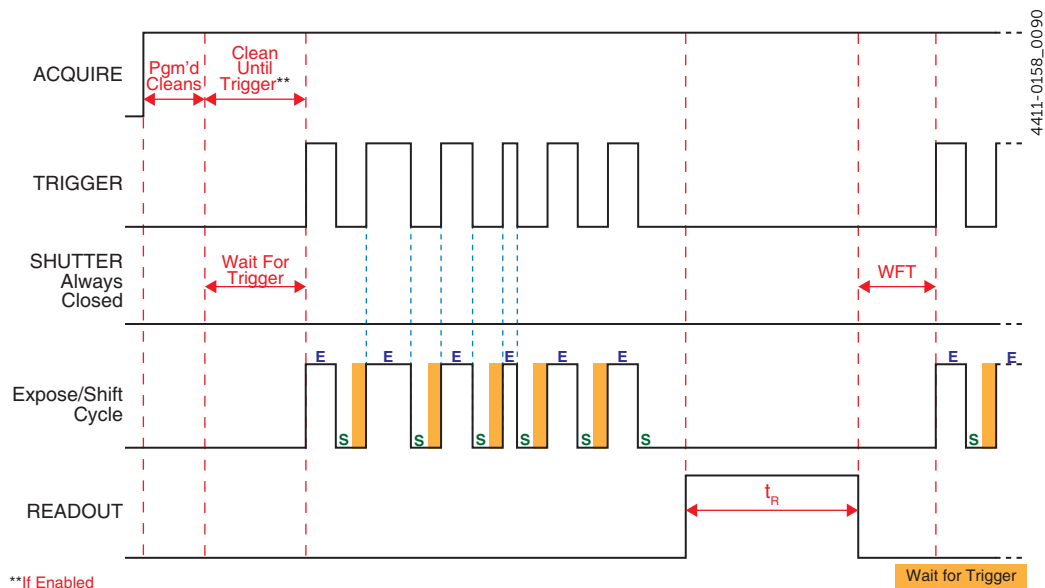
CAUTION!

The use of this mode is **strongly discouraged**. Contact Teledyne Princeton Instruments for assistance before using this shutter mode. Refer to [Contact Information](#) on page 136 for complete information.

10.2.1.5.2 Always Closed

Figure 10-15 illustrates the timing diagram for Expose During Trigger Pulse mode combined with Always Closed shutter mode.

Figure 10-15: Kinetics Timing Diagram: Expose During Trigger, Always Closed

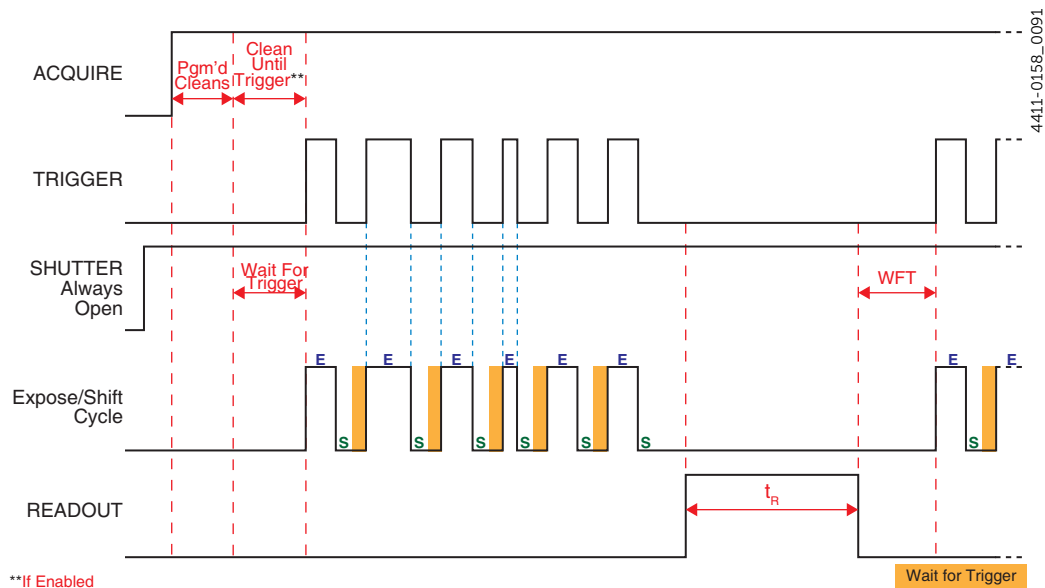


This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that a dark reference file is often unnecessary.

10.2.1.5.3 Always Open

Figure 10-16 illustrates the timing diagram for Expose During Trigger Pulse mode combined with Always Open shutter mode.

Figure 10-16: Kinetics Timing Diagram: Expose During Trigger, Always Open

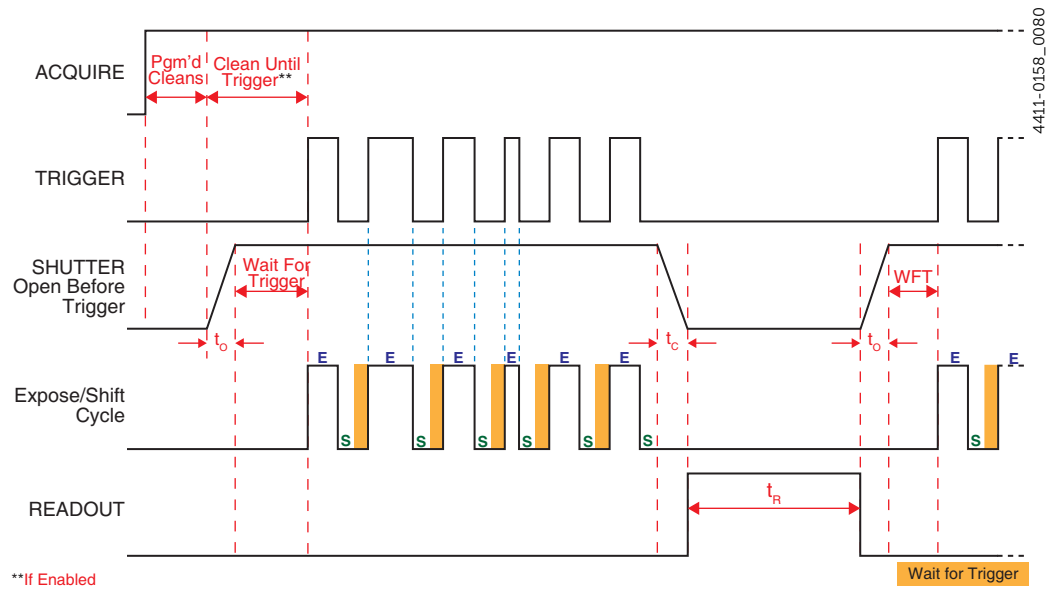


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) **Open Before Trigger** is closely related.

10.2.1.5.4 Open Before Trigger

Figure 10-17 illustrates the timing diagram for Expose During Trigger Pulse mode combined with Open Before Trigger shutter mode.

Figure 10-17: Kinetics Timing Diagram: Expose During Trigger Pulse, Open Before Trigger



10.2.2 Trigger Determined By

When using an external trigger to initiate a readout, SOPHIA-XO can be configured to respond to:

- The rising edge of the incoming trigger pulse;
- The falling edge of the incoming trigger pulse.

The Trigger Determined By parameter configures this behavior. Valid values are:

- Rising Edge;

SOPHIA-XO responds to the rising edge of incoming trigger pulses. Depending on the specific system configuration, one or more subsequent trigger pulses may be required (or ignored) by the system. Refer to [Section 10.2.1, Trigger Response](#), on page 80 for complete information about configuring incoming trigger responses.

When using [Expose During Trigger Pulse](#) mode:

- Exposure begins on the Rising Edge of each incoming trigger pulse;
- Exposure ends on the Falling Edge of the respective trigger pulse.

The timing diagrams in [Section 10.2.1.5, Expose During Trigger Pulse](#), on page 91 illustrate this.



NOTE:

If SOPHIA-XO is busy when a subsequent trigger pulse is received, the trigger is ignored.

- Falling Edge.

SOPHIA-XO responds to the falling edge of incoming trigger pulses. Depending on the specific system configuration, one or more subsequent trigger pulses may be required (or ignored) by the system. Refer to [Section 10.2.1, Trigger Response](#), on page 80 for complete information about configuring incoming trigger responses.

When using [Expose During Trigger Pulse](#) mode:

- Exposure begins on the Falling Edge of each incoming trigger pulse;
- Exposure ends on the Rising Edge of the respective trigger pulse.



NOTE:

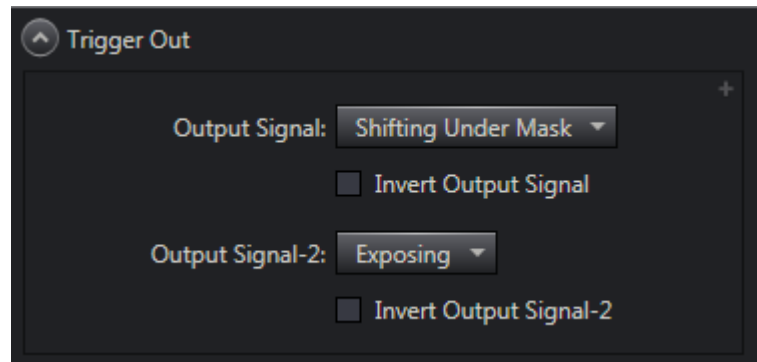
If SOPHIA-XO is busy when a subsequent trigger pulse is received, the trigger is ignored.

10.3 Trigger Out

In addition to being able to synchronize SOPHIA-XO with an experiment, additional equipment can be synchronized using the Trigger Out connector on the rear of SOPHIA-XO.

Two trigger out pulses are configured on the Trigger Out expander, shown in [Figure 10-18](#).

Figure 10-18: Typical Trigger Out Expander



4411-0158_0034

The following options are available for each of the two output signals:

- Acquiring;
The associated output signal is high when SOPHIA-XO is acquiring or ready to receive the first trigger.
- Always High;
The associated output signal is always high.
- Exposing;
The associated output signal is high when the sensor is exposed as configured within LightField.
- Reading Out;
The associated output signal when data are being read out of the sensor.
- Shifting Under Mask;
This output indicates when Kinetics shifts are occurring.
- Shutter Open;
The associated output signal is high when the shutter is open.
- Waiting for Trigger.
The associated output signal when SOPHIA-XO is waiting for an incoming trigger.

Each of these options can also be inverted to create active low signals using the Invert Output Signal option.

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Chapter 11: Binning

Binning is the process of summing data from adjacent pixels to form a single pixel, often called a Super Pixel. Binning can be accomplished in one of two ways:

- Hardware;
- Software.

Rectangular groups of pixels of any size may be binned together subject to some hardware and software limitations.

11.1 Hardware Binning

Hardware binning is performed on the CCD array before the signal is read out of the output amplifier. For signal levels that are readout noise limited this method improves S/N ratio linearly with the number of pixels grouped together. For signals large enough to render the camera photon shot noise limited, the S/N ratio improvement is roughly proportional to the square-root of the number of pixels binned.

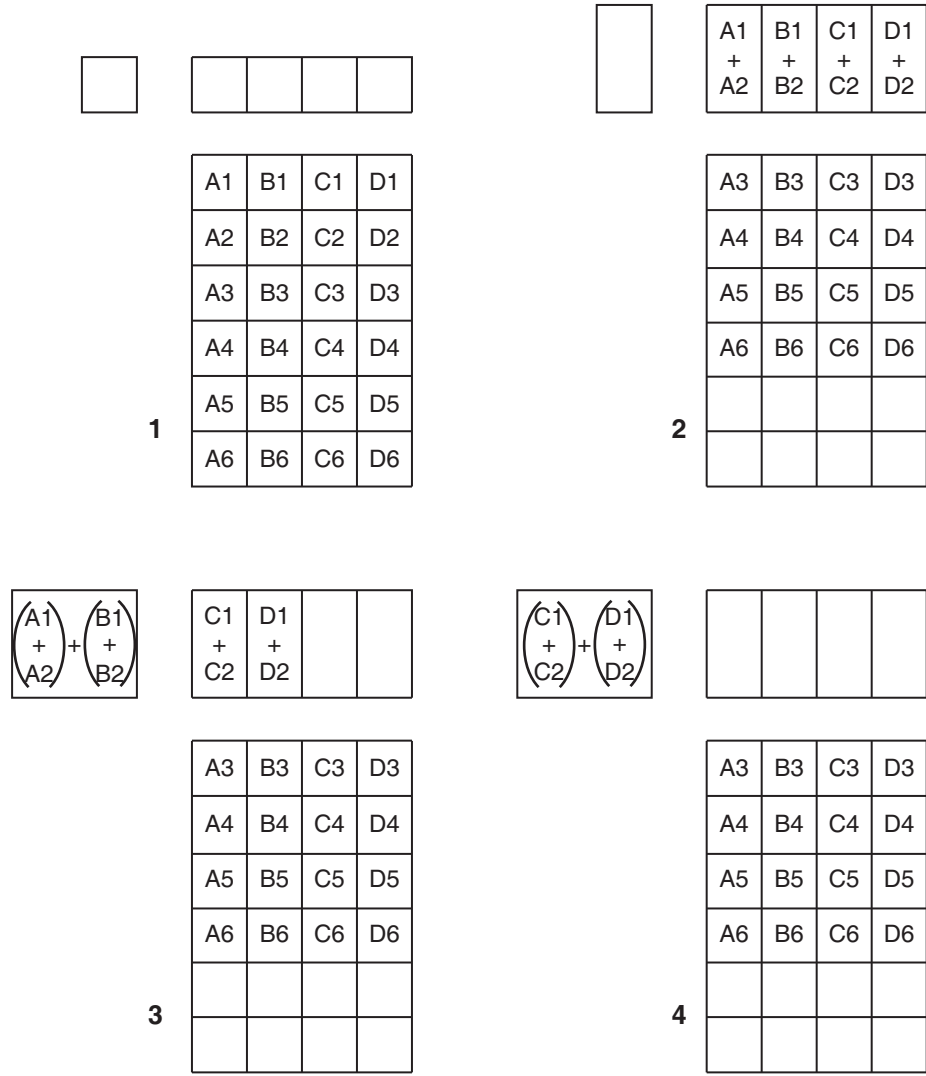
Binning reduces readout time and the burden on computer memory, but at the expense of resolution. Since shift register pixels typically hold only twice as much charge as image pixels, the binning of large sections may result in saturation and “blooming”, or spilling of charge back into the image area.

When SOPHIA-XO is configured to use multiple output ports, there are symmetry requirements when performing hardware binning:

- When SOPHIA-XO is configured to use 2-port readout, all binning regions must be symmetrical about the vertical center-line of the CCD.
- When SOPHIA-XO is configured to use 4-port readout, all regions must be symmetrical about both the vertical and horizontal center-lines of the CCD.

[Figure 11-1](#) illustrates an example of 2 x 2 binning. Each pixel of the image displayed by the software represents 4 pixels of the CCD array. Rectangular bins of any size are possible. Binning also reduces readout time and the burden on computer memory, but at the expense of resolution. Since shift register pixels typically hold only twice as much charge as image pixels, the binning of large sections may result in saturation and blooming, or spilling of charge back into the image area.

Figure 11-1: 2 x 2 Binning



4411-0158_0040

11.2 Software Binning

One limitation of hardware binning is that the shift register pixels and the output node are typically only 2-3 times the size of imaging pixels. Consequently, if the total charge binned together exceeds the capacity of the shift register or output node, the data will be corrupted.

This restriction strongly limits the number of pixels that may be binned in cases where there is a small signal superimposed on a large background, such as signals with a large fluorescence. Ideally, one would like to bin many pixels to increase the S/N ratio of the weak peaks but this cannot be done because the fluorescence would quickly saturate the CCD.

The solution is to perform the binning in software. Limited hardware binning may be used when reading out the CCD. Additional binning is accomplished in software, producing a result that represents many more photons than was possible using hardware binning.

Software averaging can improve the S/N ratio by as much as the square-root of the number of scans. Unfortunately, with a high number of scans, i.e., above 100, camera 1/f noise may reduce the actual S/N ratio to slightly below this theoretical value. Also, if the light source used is photon-flicker limited rather than photon shot-noise limited, this theoretical signal improvement cannot be fully realized. Again, background subtraction from the raw data is necessary.

This technique is also useful in high light level experiments, where the camera is again photon shot-noise limited. Summing multiple pixels in software corresponds to collecting more photons, and results in a better S/N ratio in the measurement.

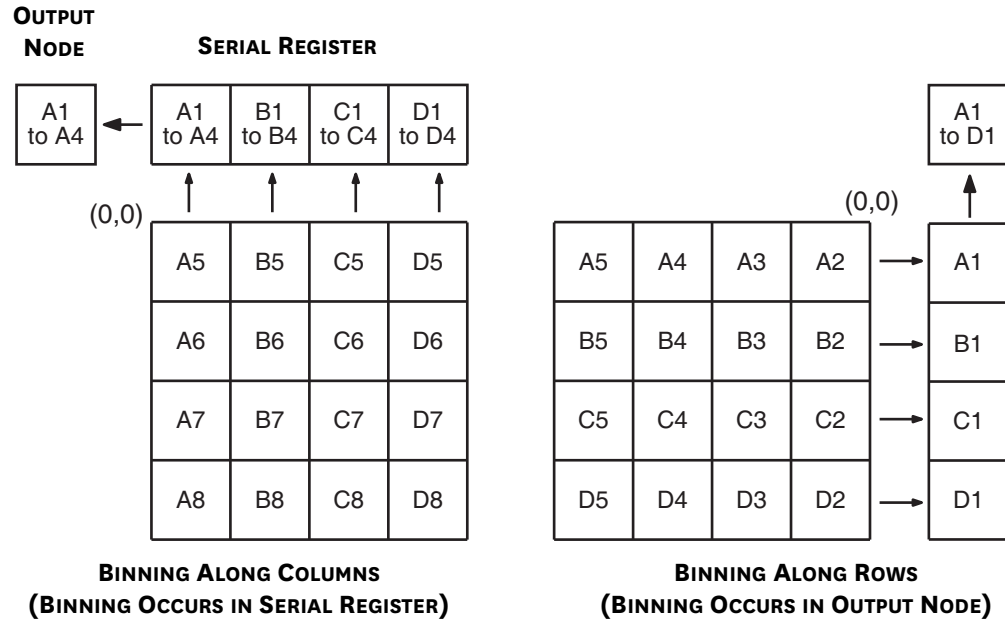
11.3 Array Orientation

Because SOPHIA-XO incorporates a square format CCD, the CCD may be positioned to perform binning along either direction of the CCD:

- Binning along columns provides maximum scan rate.
- Binning along the rows minimizes crosstalk and is therefore better for multi-spectral applications.

See [Figure 11-2](#).

Figure 11-2: Binning and Array Orientation



4411-0158_0041



NOTE:

Switching between orientations can be easily performed by rotating the camera 90° and appropriately updating the binning parameters within LightField.

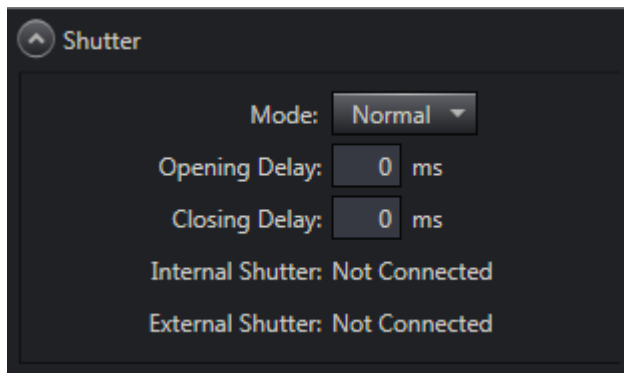
Chapter 12: Shutter Configuration and Control

This chapter provides information about the configuration and control of an external shutter that has been connected to SOPHIA-XO's.

12.1 Configuration

Shutter information is configured within LightField on the Shutter expander. [Figure 12-1](#) illustrates a typical Shutter expander when there is no external shutter installed.

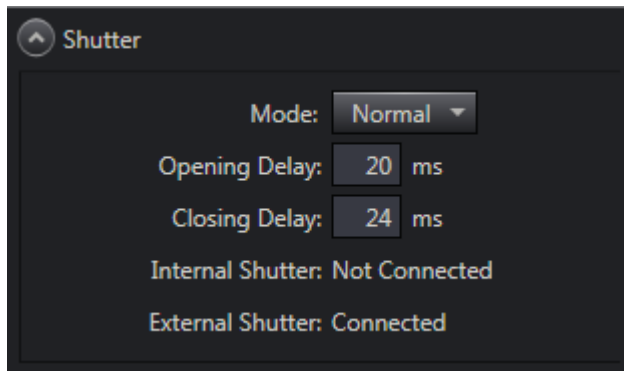
Figure 12-1: Typical Shutter Expander: No External Shutter Installed



4411-0158_0042

[Figure 12-2](#) illustrates a typical Shutter expander when an external shutter has been installed.

Figure 12-2: Typical Shutter Expander: External Shutter Installed



4411-0158_0100

12.1.1 Mode

This parameter determines the shutter's opening and closing behavior during an experiment.

Depending upon the specific Trigger In ► Trigger Response that has been selected, supported Modes are:

- Normal;
The shutter opens for exposure, and closes when complete.



CAUTION!

Although NORMAL Shutter mode is available in Kinetics Readout, programming a SOPHIA-XO for NORMAL mode when using Kinetics is **strongly discouraged**. This combination will result in high shutter repetition rates and short exposure times which may permanently damage/destroy the shutter.

Shutters are not covered by the warranty.

If an application requires both NORMAL shutter mode and Kinetics Readout, contact Teledyne Princeton Instruments for assistance prior to attempting this configuration. Refer to [Contact Information](#) on page 136 for complete information.

- Always Closed;
When selected, the shutter closes and remains in the closed position. This mode is primarily used when acquiring a dark reference file. However, SOPHIA-XO typically runs at such a low temperature that a dark reference file is often unnecessary.
- Always Open;
When selected, the shutter opens and remains open for the experiment duration. This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.)
- Open Before Trigger
When selected, the shutter opens as soon as SOPHIA-XO is ready to receive an External Sync pulse. This is required if the time between the External Sync pulse and the event is less than the time it takes the shutter to open which is a typically a few milliseconds.

12.1.2 Opening Delay

Specifies, in milliseconds, the length of time SOPHIA-XO is to wait for the active shutter to open.

Valid values are [0 ... 1000] ms, inclusive, in 1 ms increments.

12.1.3 Closing Delay

Specifies, in milliseconds, the length of time SOPHIA-XO is to wait for the active shutter to close.

Valid values are [0 ... 1000] ms, inclusive, in 1 ms increments.

12.1.4 Internal Shutter

Indicates the connection status of SOPHIA-XO's internal shutter.

**NOTE:**

This status will always be Not Connected.

12.1.5 External Shutter

Indicates the connection status of an external shutter.

**CAUTION!**

In order to prevent potential permanent damage to either the SOPHIA-XO camera and/or the shutter, always contact Teledyne Princeton Instruments before connecting an external shutter that is not listed in [Table 2-4, Supported External Shutters](#), on page 24 to a SOPHIA-XO. Refer to [Contact Information](#) on page 136 for complete information.

12.2 Using an External Shutter

**WARNING! RISK OF ELECTRIC SHOCK!**

The shutter drive can apply voltage up to **70V** to an external shutter. Therefore, when using a shutter not supplied by Teledyne Princeton Instruments, it is the responsibility of each user to assure all connections, other than ground, to the external shutter are insulated to prevent accidental contact by personnel.

Although not mandatory, Teledyne Princeton Instruments strongly recommends the use of shielded cable with braided shield between the shutter and the shutter connector. The shield braid should be connected to the shell of the Hirose connector in accordance with Hirose's recommendations for connecting shield grounds.

Usually, it is best to connect the shield ground to the frame of the external shutter, but this may vary with the circumstances. Although the use of a braided shield typically reduces the susceptibility of a system to electromagnetic disturbances, this protection is not guaranteed in all applications.

**CAUTION!**

In order to prevent potential permanent damage to either the SOPHIA-XO camera and/or the shutter, always contact Teledyne Princeton Instruments before connecting an external shutter that is not listed in [Table 2-4, Supported External Shutters](#), on page 24 to a SOPHIA-XO. Refer to [Contact Information](#) on page 136 for complete information.

LightField automatically detects when an external shutter has been connected to SOPHIA-XO. By default, the external shutter configured for use is a Prontor Magnetic 0 (23 mm).

When using a different supported shutter (refer to [Table 2-4, Supported External Shutters](#), on page 24 for a list of supported shutters,) before beginning to configure parameters or acquiring data, the correct device must be selected via the Shutter Configuration Add-In, which is accessed within LightField via the Add-ins tab.

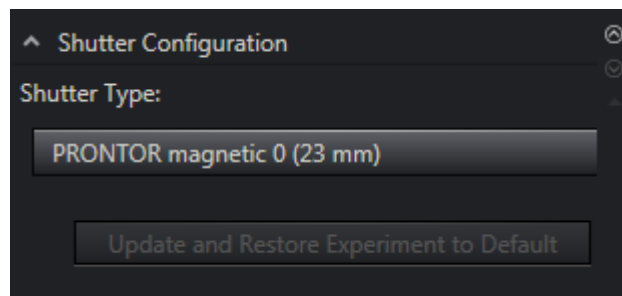


NOTE:

If the Shutter Configuration add-in is not shown on the Add-ins tab, within LightField select Application Menu ► Manage Add-ins..., click on the corresponding check box, and click OK.

[Figure 12-3](#) illustrates a typical Shutter Configuration add-in with the default shutter selected.

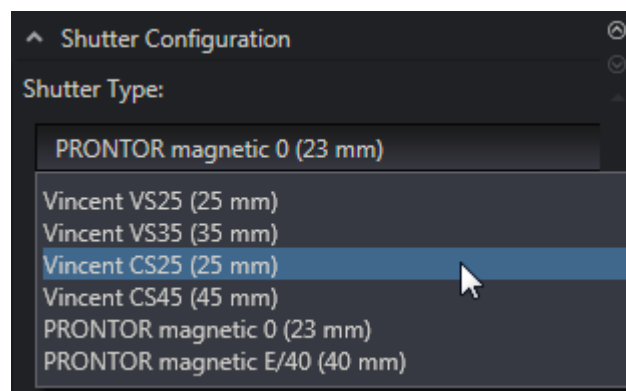
Figure 12-3: Typical Shutter Configuration Add-In: Default External Shutter



4411-0158_0099

To select an alternative, supported shutter, click on the Shutter Type: field to display a pull-down menu of all supported shutters, and click on the shutter that is being used. For example, the Vincent CS25 (25 mm) shutter is to be used, as shown in [Figure 12-4](#).

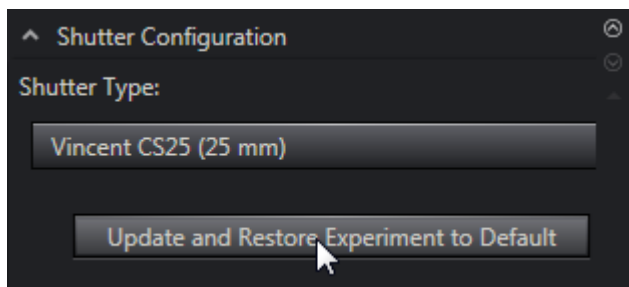
Figure 12-4: Typical Shutter Type Menu



4411-0158_0100

Once the new shutter has been selected, the Update and Restore Experiment to Default action is then enabled. See [Figure 12-5](#).

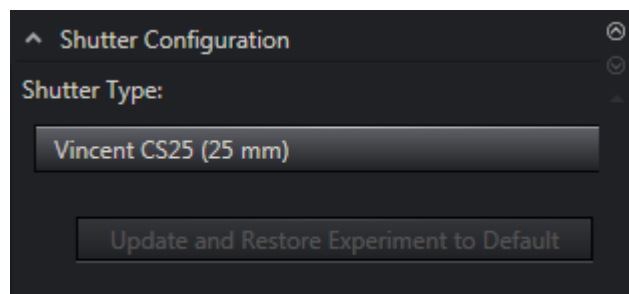
Figure 12-5: Typical Update Shutter Type Action



4411-0158_0101

Click on Update and Restore Experiment to Default to update the external shutter information within the SOPHIA-XO system. The Shutter Type: now reflects the selected shutter, similar to that shown in [Figure 12-6](#).

Figure 12-6: Typical Updated Shutter: Non-Default Shutter Selected



4411-0158_0102

The remaining experiment parameters may now be configured.

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Appendix A: Technical Specifications



CAUTION!

All specifications are subject to change.

This appendix provides some technical information and specifications for SOPHIA-XO cameras and optional accessories. Additional information may be found on data sheets available on the Teledyne Princeton Instruments website (www.princetoninstruments.com).

A.1 System Dimensions and Weight

Refer to [Table A-1](#) for system dimensions and weight.

Table A-1: General System Specifications

Dimension	Specification
Length	9.91 in [25.16 cm]
Width	5.08 in [12.90.0 cm]
Height	5.62 in [14.28 cm]
Weight	16.5 lbs [7.5 kg]

A.2 Camera Specifications

Refer to [Table A-2](#) for CCD array specifications for SOPHIA-XO detectors.

Table A-2: CCD Array Specifications^a (Sheet 1 of 2)

Specification	SOPHIA-XO 2048 eXcelon	SOPHIA-XO 2048-13.5 μ m
CCD	e2v CCD230-42	e2v CCD42-40 AIMO BI
Image Type	Monochrome	
Resolution	2048 x 2048	
Pixel Size	15 μ m x 15 μ m	13.5 μ m x 13.5 μ m
Imaging Area	30.7 mm x 30.7 mm	27.6 mm x 27.6 mm
Frame Rate ^b	3.20 fps (full frame)	1.38 fps (full frame) ^c
Readout Amplifiers (Ports)	4	2
ADC Speed/16 bits ^d	400 kHz, 4 MHz, 16 MHz	200 kHz, 2 MHz, 8 MHz ^e
Vertical Shift Rate ^f	24 μ sec/row	39 μ sec/row

Table A-2: CCD Array Specifications^a (Sheet 2 of 2)

Specification	SOPHIA-XO 2048 eXcelon	SOPHIA-XO 2048-13.5 μ m	
		Low Noise	High Capacity
Read Noise			
100 kHz	4.5 e ⁻ rms	3.5 e ⁻ rms	11 e ⁻ rms
1 MHz	8.5 e ⁻ rms	8 e ⁻ rms	20 e ⁻ rms
4 MHz	22 e ⁻ rms	20 e ⁻ rms	60 e ⁻ rms
Non-linearity (typical)	< 2% @ 100 kHz	< 1.5% @ 100 kHz	
Optical Focal Distance	1.87" [47.50 mm]		

- a. Specifications are valid as of the publication date of this manual. For up-to-date specifications, refer to the SOPHIA-XO data sheets available for download from www.princetoninstruments.com.
- b. @ 4 MHz, 4-port readout, 24 μ s vertical shift rate
- c. @ 2 MHz, 2-port readout, 39 μ s vertical shift rate
- d. 4-port readout
- e. 2-port readout
- f. Software programmable

A.2.1 Thermal Characteristics

Refer to [Table A-3](#) for specific thermal information.

Table A-3: Default Operating Temperature

Specification	Cooling Medium	Specification
Default Operating Temperature	Air	-80°C
	Liquid ^a	-80 °C
Deepest Cooling Temperature	Air	Lower than -90 °C
	Liquid ^a	
Precision	–	\pm 0.05 °C

- a. External coolant circulator required.

A.3 Power Specifications

All voltages required by SOPHIA-XO cameras are generated and delivered by an external power supply included with each SOPHIA-XO camera using the supplied cables.

Power to the camera is switched on and off using the rocker switch on the external power supply.



WARNING!

In case of a fire or other emergency, immediately remove the power supply's AC plug from the wall receptacle.



CAUTION!

Use of a power supply other than that provided with the SOPHIA-XO camera will void the camera warranty. For specific power supply requirements, contact Teledyne Princeton Instruments. Refer to [Contact Information](#) on page 136 for complete information.

Refer to [Table A-4](#) for power specifications for the external SOPHIA-XO power supplies.

Table A-4: Power Specifications

Parameter	Specification	Units
Input Voltage (nominal)	100 – 240	V _{AC}
Input Frequency (nominal)	50 – 60	Hz
Input Power (maximum)	410	W

A.4 Environmental Specifications

Refer to [Table A-5](#) for environmental specifications.

Table A-5: SOPHIA-XO Environmental Specifications

Parameter	Specification		
	Minimum	Nominal	Maximum
Storage Temperature	-20°C		+55°C
Operating Temperature	+5°C		+30°C
Operating Ambient Relative Humidity	<80% (non-condensing)		
Operating Ambient Temperature ^a	0°C		+20°C

a. Although operation to -25°C is achievable, operation below 0°C is not guaranteed.



NOTE:

Cooling performance may degrade if the room temperature is above +23°C.

A.4.1 Ventilation

A minimum of 1 inch (2.54 cm) clearance is required around all vents on the SOPHIA-XO camera.

Where SOPHIA-XO is within an enclosure, >30 cfm air circulation and heat dissipation of 250 W is required.

A.5 External Coolant Circulator Specifications



CAUTION!

Never set the coolant temperature below the dew point.

Refer to [Table A-6](#) for external coolant circulator specifications.

Table A-6: External Coolant Circulator Specifications

Parameter	Specification
Coolant Flow Rate	0.8 gal/minute max
Coolant Pressure	20.0 psi max
Minimum Heat Load	160 W

A.6 Shutter Specifications

Refer to [Table A-7](#) for technical specifications for external, non-X-ray shutters supported by SOPHIA-XO.

Table A-7: SOPHIA-XO External Shutter (Non-X-Ray) Specifications

Parameter	Specification					
	Vincent				PRONTOR Magnetic	
	VS25	VS35	CS25	CS45	0	E/40
Shutter Aperture	25 mm	35 mm	25 mm	45 mm	23 mm	40 mm
Shutter Open Time, t_o	6.0 ms	18.0 ms	12.0 ms	20.0 ms	12 ms	15 ms
Shutter Closing Time, t_c	5.0 ms	12.0 ms	14.0 ms	24.0 ms	12 ms	15 ms
Minimum Exposure Time	6.0 ms	20.0 ms	15.0 ms	25.0 ms	19.2 ms	40 ms
Maximum Repetition Rate	10 Hz	5 Hz	5 Hz	2.5 Hz	—	—
Shortest Time Between Two Exposures	—	—	—	—	1 s	1 s

A.6.1 SHUTTER Connector



CAUTION!

In order to prevent potential permanent damage to either the SOPHIA-XO camera and/or the shutter, always contact Teledyne Princeton Instruments before connecting an external shutter that is not listed in [Table 2-4, Supported External Shutters](#), on page 24 to a SOPHIA-XO. Refer to [Contact Information](#) on page 136 for complete information.

External shutters must be equipped with a compatible shutter connector in order to plug into the external SHUTTER connector located on the rear of the SOPHIA-XO camera (see [Figure 2-4](#) on page 20). Shutters that have been supplied by Teledyne Princeton Instruments will be equipped with the proper connector.

However, when using a non-Teledyne Princeton Instruments' supplied shutter, refer to [Table A-8](#) for information about the required shutter connector.

Table A-8: External SHUTTER Connector Information

Manufacturer	Part Number
Hirose	HR10-7P-4P (73)

Refer to [Table A-9](#) for the SHUTTER connector pinout.

Table A-9: SHUTTER Connector Pinout

Pin Number	Description
1	SHUTTER +
2	SHUTTER -
3	No Connection
4	No Connection

A.7 Minimum Host Computer Specifications

**NOTE:**

Computers and operating systems experience frequent updates. Therefore, the following sections are intended to provide minimum system requirements for operating a SOPHIA-XO camera.

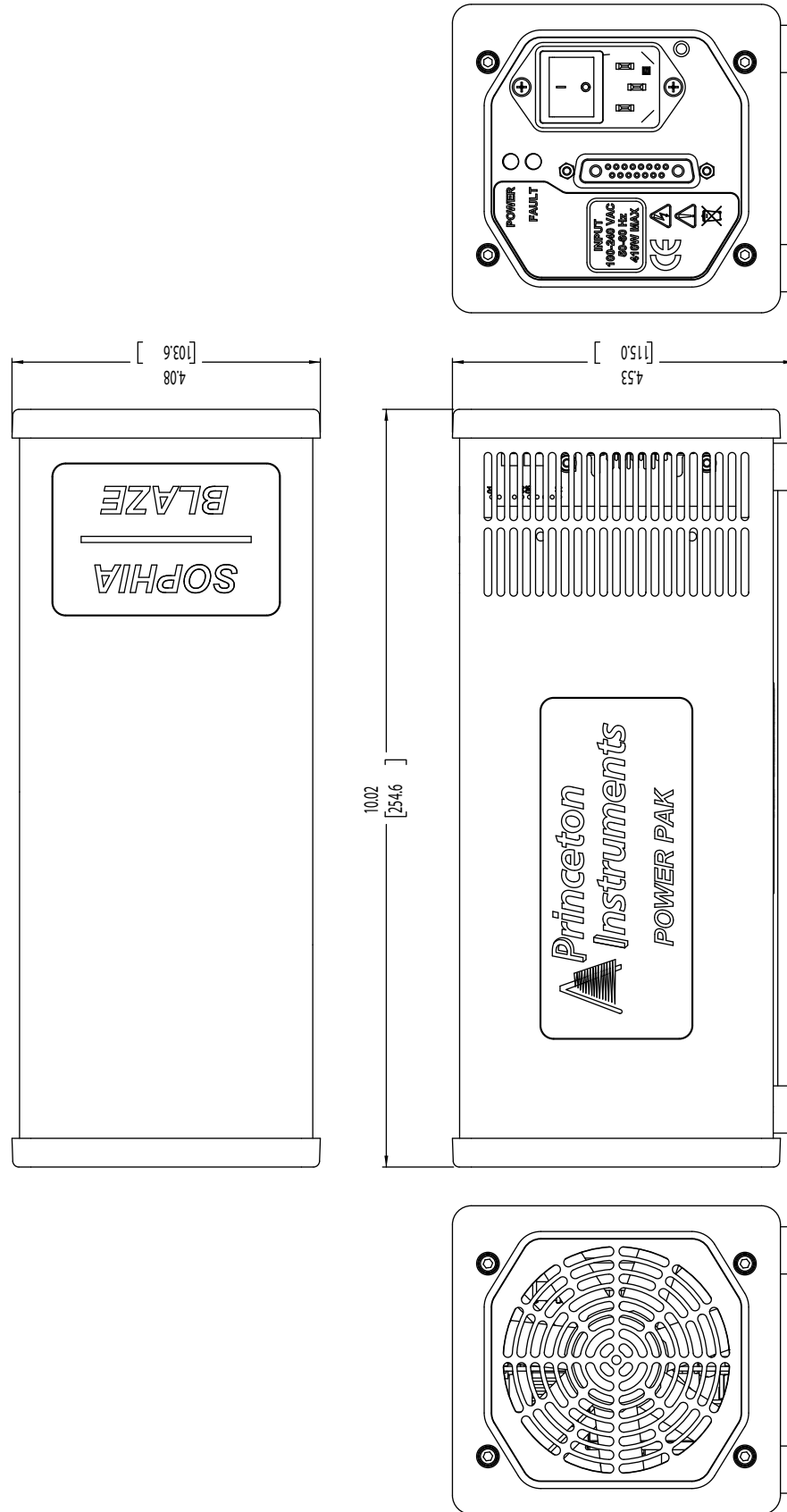
A faster computer with 5 GB or larger memory (RAM) will greatly enhance the software performance during live mode operations.

Contact the factory to determine specific requirements.

The minimum system requirements for LightField are:

- Windows 7/8/10 (64-bit)
- 2 GHz dual core processor
- 4 GB RAM (or greater)
- CD-ROM drive
- Super VGA monitor and graphics card supporting at least 65535 colors with at least 128 MB of memory. Memory requirement is dependent on desired display resolution.
- Hard disk with a minimum of 1 GB available for installation. Additional space is required for data storage: the amount of space required depends on the number and size of images/spectra collected. Disk level compression programs are not recommended. Drive speed of 10,000 RPM recommended.
- Mouse or other pointing device.

Figure B-2: Outline Drawing: SOPHIA-XO Power Supply



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Appendix C: Custom Modes

This appendix describes advanced ways of maximizing data acquisition rates in Full Frame mode.

C.1 Custom Sensor

In addition to Binning and Regions of Interest, Custom Sensor can be used to reduce Readout Time by reducing the apparent size of the CCD array.



CAUTION!

Teledyne Princeton Instruments does not encourage users to change these settings. For most applications, default values provide the best results. It is strongly advised that users contact the factory for assistance before customizing the chip definition.

Custom Sensor redefines the size of the CCD's active area via software. Unlike setting a smaller Region of Interest (ROI), which also involves reading out fewer pixels, this mode does not incur overhead from discarding or skipping the rest of the rows. And, unlike both Binning and ROI, Custom Sensor relies on a form of array masking to ensure that no light falls outside the currently set active area.

The Custom Sensor pane, illustrated in [Figure C-1](#), is accessed by opening the Sensor expander and clicking on the Custom Sensor button.

Figure C-1: Custom Sensor Pane



By changing the values in the Active fields, image acquisition speed can be increased by reducing the size of the active area in the definition. The result will be faster, but lower resolution, data acquisition. Operating in this mode would ordinarily require that the chip be masked so that only the reduced active area is exposed. This will prevent unwanted charge from spilling into the active area or being transferred to the shift register.

By default, if there are no Pre-Dummy rows, the serial register will be cleared before rows are shifted.

**NOTE:**

Clean Serial Register is enabled on the Sensor Cleaning pane only when Inactive Area Top Margin is configured to 0 rows. Deselect the check box to deactivate the serial register cleaning.

C.1.1 Custom Timing

**NOTE:**

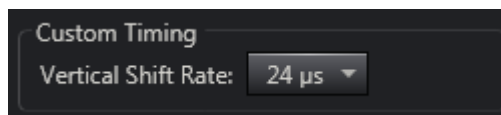
Custom Timing is standard within LightField for full frame CCD cameras.

Custom Timing allows a faster vertical shift time to be specified, and is configured using the Custom Sensor button on the Sensor expander.

Vertical shift rate is the time required to shift one row into the serial register. The smaller the value, the faster charge will be shifted up one row at a time toward the serial register.

In the Custom Timing panel, vertical shift rate is configured by selecting the desired rate from the pull-down menu, as illustrated in [Figure C-2](#).

Figure C-2: Custom Timing



Appendix D: Drain Coolant from SOPHIA-XO

This appendix provides information necessary to safely drain coolant from within the SOPHIA-XO camera body.

1. Place SOPHIA-XO camera body on a flat, secure surface with the two coolant fittings facing down and positioned over a container that will collect the coolant as it is draining. See [Figure D-1](#).

Figure D-1: Positioning SOPHIA-XO to Drain Coolant



4411-0158_0102

- Using two small screwdrivers, Allen wrenches, or similar tools, carefully depress the center piston on each coolant fitting simultaneously. See [Figure D-2](#)

Figure D-2: Depressing Coolant Fittings' Center Pistons



4411-0158_0103

CAREFULLY DEPRESS USING TWO SMALL SCREWDRIVERS, ALLEN WRENCHES, OR SIMILAR TOOLS.

This will allow the coolant to drain out of the SOPHIA-XO and into the collection bucket.



NOTE:

It is not necessary to drain every drop of coolant out of the SOPHIA-XO, but always drain as much as reasonably possible.

3. When the coolant has drained, release the pistons and verify that they return to their normal, closed position.
4. Use a soft cloth to wipe off any stray coolant from the SOPHIA-XO and/or surrounding areas.
5. If available, install rubber fitting covers onto the coolant fittings prior to shipping or storing the SOPHIA-XO.
6. Dispose of drained coolant according to local standards/requirements.

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Appendix E: Backfilling for Storage or Shipment

To protect the camera while in storage or during shipment, you need to re-mount the shipping plate to the front of the camera: this plate was mounted to the camera before it was shipped to you from the factory. In addition, you will need to backfill the camera with dry Nitrogen.



WARNING!

Verifying that the CCD mask is in place and slowly opening the valve prevents potential damage to fragile parts.

Perform the following procedure to backfill a SOPHIA-XO camera:

1. Verify that the CCD mask is in place. The mask may have a square or rectangular opening depending on the CCD.
2. Using the original bolts and rubber ConFlat gasket, mount the shipping plate to the face of the camera. Tighten down the bolts at this time. [Figure E-1](#) illustrates a shipping plate that is already installed.

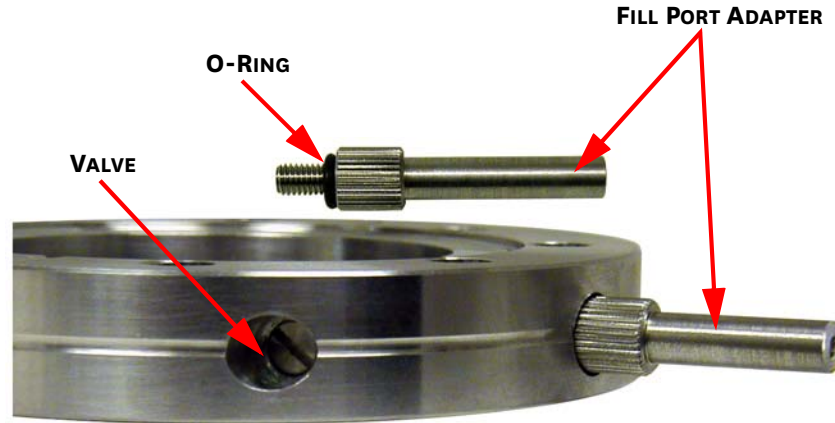
Figure E-1: Shipping Plate Mounted to Camera



4411-0158_0101

- Using a flat-blade screwdriver, close the valve (i.e., screw it in completely.) See [Figure E-2](#).

Figure E-2: Shipping Plate Valve and Fill Port Adapter



4411-0158_0098

- If it is not already attached to the shipping plate, screw in the fill port adapter (with O-ring).
- Attach a hose from a dry nitrogen source to the fill port adapter.
- Start the dry nitrogen flow at 1 Atmosphere maximum and slowly open the valve to allow the gradual displacement of air with the dry nitrogen. You should feel gas exiting from the open valve.
- When the valve is fully open, continue the gas flow for at least five (5) minutes to insure the backfill compartment is completely filled with dry nitrogen and all of the moisture is out.
- Close the valve.
- Shut off the gas flow and remove the hose. You can leave the fill port adapter in place or you can remove and store it.
- The SOPHIA-XO camera is now ready for shipment or storage.

Appendix F: Troubleshooting



WARNING!

Do not attach or remove any cables while the camera system is powered on.

The SOPHIA-XO power supply is equipped with a red FAULT LED on its rear panel. When the system is operating normally, this LED is extinguished. However, when an error has been detected, the number of times the LED flashes is indicative of the specific fault. Refer to [Table F-1](#) for additional information.

Table F-1: Fault LED Error Codes

Flashes	Error/Fault	Refer to...
1	TEC Overcurrent	
2	Shutter Power Supply Overcurrent	Shutter Power Supply Overcurrent on page 128
SOLID	Connection Failure	Connection Failure or Logic Power Supply Overcurrent on page 124



NOTE:

A Logic Power Supply Overcurrent error is an improbable event.

- If the red LED is on solid, first check the cable.
 - If the cable is not at fault, the system will most likely have to be returned for service. Refer to [Contact Information](#) on page 136 for complete information.
-

Additional troubleshooting guidelines for issues that may occur while working with a SOPHIA-XO system are provided. Refer to [Table F-2](#) for specific troubleshooting sections.

Table F-2: Troubleshooting Index by Error/Fault Description (Sheet 1 of 2)

Error/Fault	Refer to...
Overexposed CCD	page 124
Baseline Signal Suddenly Changes	page 124
Camera Stops Working	page 125
Temperature Lock Cannot be Achieved or Maintained	page 125
Camera Loses Temperature Lock	page 126
Gradual Deterioration of Cooling Capability	page 126

Table F-2: Troubleshooting Index by Error/Fault Description (Sheet 2 of 2)

Error/Fault	Refer to...
External Coolant Circulator: Low Coolant (Air in the Hoses)	page 127
Shutter Faults/Errors	page 128
Devices Missing	page 129
Device is Occupied	page 130
Acquisition Started but Viewer Display Does Not Update	page 130

F.1 General Camera Faults/Errors

This section provides information about troubleshooting general camera faults and errors.

F.1.1 Connection Failure or Logic Power Supply Overcurrent

This failure is indicated by the red FAULT LED on the rear of the SOPHIA-XO power supply being ON (i.e., does not flash.)

Examine the primary power cable and repair/replace as necessary.

Verify all connectors are fully seated at both ends and the jack screws are secured.



NOTE:

A Logic Power Supply Overcurrent error is an improbable event. In the event that the red LED is on SOLID:

- Examine the primary power cable.
- If the cable is not at fault, the system will most likely have to be returned for service. Refer to [Contact Information](#) on page 136 for complete information.

F.1.2 Overexposed CCD

It takes an enormous power density to damage the CCD at room temperature or cooled. It can be done (e.g., imaging the sun with a large aperture lens, so that the silicon is heated.)

What can happen if the CCD is cold is a temporary elevation of the dark current. If the CCD is over-saturated, electrons pool in the substrate and are clocked out slowly (over hours or even days). To clear the charge, it is best to return the CCD to room temperature, then run the CCD (set short exposure, then click run in LF) while it is cooled down to normal operating temperature.

F.1.3 Baseline Signal Suddenly Changes

A change in the baseline signal is normal if the temperature, gain, or speed setting has been changed. If this occurs when none of these settings have been changed, there may be excessive humidity in the camera vacuum enclosure. Turn off the camera and contact Teledyne Princeton Instruments Customer Support. Refer to [Contact Information](#) on page 136 for complete information.

F.1.4 Camera Stops Working

Problems with the host computer system or software may have side effects that appear to be hardware problems. If you are sure the problem is in the camera system hardware, perform these preliminary system checks:

- Examine the two LEDs on the rear panel of the power supply.
When the power supply is operating properly, the two LED statuses should be:
 - Green POWER LED is ON;
If the POWER LED is extinguished, it may indicate a blown fuse or general power outage.
 - Red FAULT LED is OFF and not flashing.
If the FAULT LED is either flashing or constantly ON, refer to [Table F-1, Fault LED Error Codes](#), on page 123 for additional information.
- Turn off all AC power.
- Verify that all cables are securely fastened.
- Turn the system back on.
The shutter should be heard opening and closing (i.e., 2 clicks approximately 1 second apart.) Contact Customer Support for further instructions.

If the system still does not respond, contact Customer Support. Refer to [Contact Information](#) on page 136 for complete information.

F.2 Cooling Faults/Errors

This section provides recommended troubleshooting guidelines for cooling-related issues.

F.2.1 Temperature Lock Cannot be Achieved or Maintained



CAUTION!

The most probable cause of a failure to lock is the setpoint has been programmed for a temperature lower than SOPHIA-XO can achieve. Return the temperature setpoint to -80°C , the default for SOPHIA-XO.

Possible causes for not being able to achieve or maintain lock include:

- Ambient temperature greater than $+23^{\circ}\text{C}$. If the ambient temperature is greater than $+23^{\circ}\text{C}$, either cool the camera's environment or raise the set temperature.
- Airflow through the camera and/or circulator is obstructed. The camera needs to have approximately 2" [50.8 mm] of clearance around the vented covers. If there is an enclosure involved, the enclosure needs to have unrestricted flow to an open environment. The camera vents its heat out the vents near the nose. The air intake is near the rear of the camera.
- A hose is kinked. Unkink the hose.
- Coolant level is low. Add coolant. Refer to [Section F.2.4, External Coolant Circulator: Low Coolant \(Air in the Hoses\)](#), on page 127.
- There may be air in the hoses. Add coolant. Refer to [Section F.2.4, External Coolant Circulator: Low Coolant \(Air in the Hoses\)](#), on page 127.
- Circulator pump is not working. If you do not hear the pump running when the external coolant circulator is powered on, turn off the circulator and contact Customer Support. Refer to [Contact Information](#) on page 136 for complete information.

- The circulator is higher than the camera. Reposition the circulator so that it is 6" [150 mm] or more below the camera. The vertical distance should not exceed 10 feet [3 m]. Typically, the camera is at table height and the circulator is on the floor.
- The camera's internal temperature may be too high which may occur if the operating environment is particularly warm or when attempting to operate at a temperature colder than the specified limit. SOPHIA-XO cameras are equipped with a thermal-protection switch that shuts the cooler circuits down if the internal temperature exceeds a preset limit. Typically, camera operation is restored automatically after approximately ten minutes. Although the thermo-protection switch will protect the camera, it is nevertheless advised to power down the camera and correct the operating conditions that caused the thermal-overload to occur.
- The camera vacuum has deteriorated and needs to be refreshed. Contact Customer Support. Refer to [Contact Information](#) on page 136 for complete information.

F.2.2 Camera Loses Temperature Lock

The internal temperature of the camera is too high. This might occur when the operating environment is particularly warm or when attempting to operate at a temperature colder than the specified limit. If this happens, an internal thermal overload switch will disable the cooler circuits to protect them. Typically, camera operation is restored in about ten minutes. Although the thermal overload switch will protect the camera, users are advised to power down and correct the operating conditions that caused the thermal overload to occur.

Additionally, repeated cycling can reduce the lifetime of the thermoelectric cooling system.

F.2.3 Gradual Deterioration of Cooling Capability

While unlikely with the SOPHIA-XO camera (guaranteed permanent vacuum for the life of the camera), if a gradual deterioration of the cooling capability is observed, there may be a gradual deterioration of the camera's vacuum. This can affect temperature performance such that it may be impossible to achieve temperature lock at the lowest temperatures. In the kind of applications for which cooled CCD cameras are so well suited, it is highly desirable to maintain the system's lowest temperature performance because lower temperatures result in lower thermal noise and better the signal-to-noise ratio. Contact the factory to make arrangements for returning the camera to the support facility. Refer to [Contact Information](#) on page 136 for complete information.

F.2.4 External Coolant Circulator: Low Coolant (Air in the Hoses)



WARNING!

If more than 2" [50.8 mm] of a coolant line is filled with air, the pump will stop working and may be damaged. If flow stops while the pump is on, turn off the external coolant circulator and add coolant.

1. Unscrew the reservoir cap and verify that the coolant reservoir contains coolant. If additional coolant is required, fill with a 50:50 mixture of water and ethylene glycol.
2. Screw the reservoir cap back in.
3. Make sure the power switch is turned off before plugging the circulator in.
4. Plug the circulator into a 100-240 V_{AC}, 47-63 Hz power source.
5. Turn the circulator on. Make sure there are no leaks or air bubbles in the hoses.



NOTE:

Small air bubbles (about the size of bubbles in soda) are common, particularly at start up and do not prevent proper operation.

- If no problems are observed, proceed to step 6.
 - If there are leaks or air bubbles, turn the circulator off and correct the problem(s) by securing the hoses or adding more coolant to the reservoir. Turn the circulator back on. Recheck and if there are no problems, proceed to step 6.
6. Turn the camera on.
 7. Launch LightField.

F.3 Shutter Faults/Errors

SOPHIA-XO's shutter has a Minimum Exposure Time (MET) of 25 ms. Operating the shutter in Normal mode with exposure times significantly shorter than the MET will not only result in incomplete CCD exposure (i.e., the shutter may not have time to open completely before starting to close,) but will also lead to premature shutter wear and eventually complete shutter failure.

High repetition rates and short exposure times will rapidly increase the number of shutter cycles and hasten the time when the shutter will have to be replaced.

Shutter replacement is typically done at the factory. If you find that the shutter on your camera is malfunctioning, contact the factory to arrange for a shutter-replacement repair.

**NOTE:**

Shutters are not covered by the warranty.

This section provides information about troubleshooting shutter-related issues.

F.3.1 Overexposed or Smeared Images

Verify that the shutter is opening and closing correctly. Potential shutter problems include:

- Complete shutter failure
The shutter no longer operates at all.
- The shutter may be stuck open
Result is overexposed or smeared images.
- The shutter may be stuck closed;
Result is no images acquired.
- One leaf of the shutter may break and no longer actuate.

F.3.2 Shutter Power Supply Overcurrent

When the red FAULT LED on the rear of the SOPHIA-XO power supply blinks three times, it indicates that a shutter power supply overcurrent has been detected.

Immediately halt the current experiment and cycle power to the camera to clear the fault.

- If the error does not return, it was a false alarm, and the experiment may continue.
- If, however, the error persists, the camera must be returned for factory service since SOPHIA-XO incorporates an internal shutter that is not user-serviceable. Refer to [Contact Information](#) on page 136 for complete information.

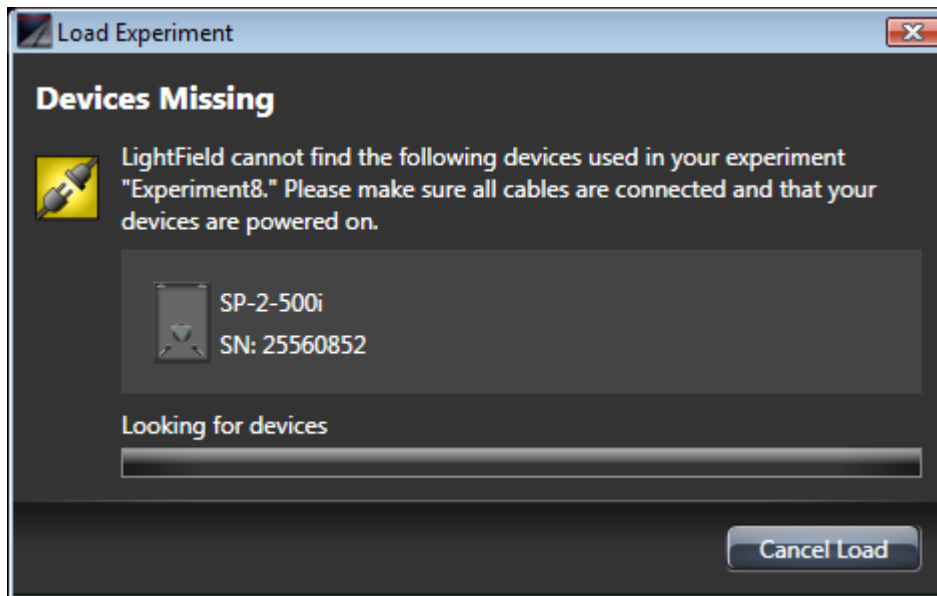
F.4 LightField Faults/Errors

This section provides information about troubleshooting problems that may occur with LightField.

F.4.1 Devices Missing

When LightField is started, it looks for devices that are powered on and connected via a communications interface to the host computer. If it cannot find a device that was used in the last experiment, the dialog shown in [Figure F-1](#) is displayed while LightField continues searching for the missing device.

Figure F-1: Devices Missing Dialog



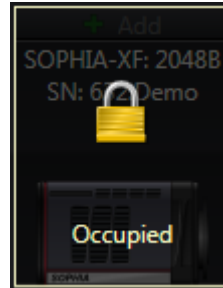
Perform the following steps to try to resolve this fault:

- Verify the device is connected and powered on.
If the device is connected but turned off, switch it on.
LightField should now find the device. If it does not, cancel the load and restart LightField.
- Cancel the loading of the experiment.
Canceling an experiment's loading means that the last used experiment will not be loaded automatically when LightField opens. However, the experiment may be loaded after all devices are available, a new experiment design can be started, or a different experiment can be loaded which uses the devices that are available.

F.4.2 Device is Occupied

Although multiple instances of LightField can be running at the same time, any device that is currently in use by one instance of LightField will be shown within the Available Devices area of all other instances as Occupied. See [Figure F-2](#).

Figure F-2: Typical LightField Occupied Device



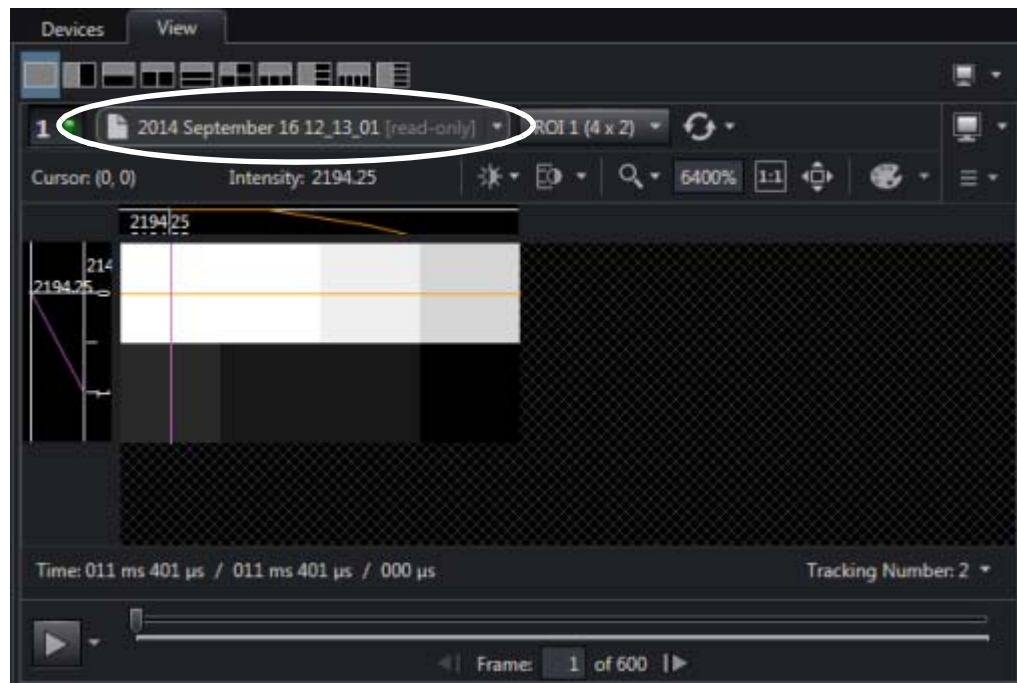
4411-0158_0071

To have a device become available to the current instance of LightField, either remove it from the Experiment Devices area in the other instance or close the instance that is using the device.

F.4.3 Acquisition Started but Viewer Display Does Not Update

Live data being acquired in either Preview or Acquire mode are displayed in a Data Viewer tab on the Experiment workspace. If the active Data Viewer's display is not being updated and data acquisition is occurring, determine if there is a filename displayed within the active Data View tab. See [Figure F-3](#).

Figure F-3: Typical Acquisition Display



4411-0158_0069

When a filename is listed, it indicates that the data being displayed are static (i.e., data from the indicated file,) and not live data that are currently being acquired.


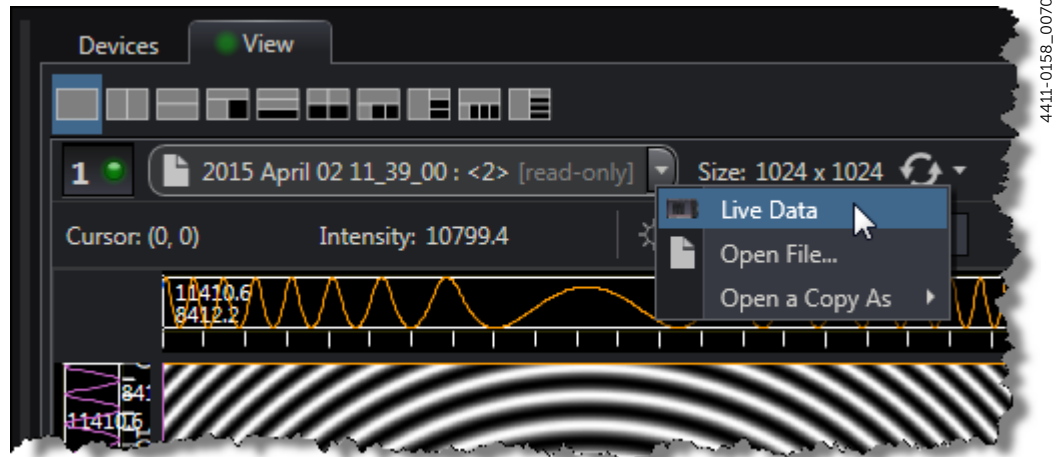
To return to a live data view, click on the  to the right of the filename to view the pull-down menu and select **LIVE DATA**. See [Figure F-4](#).

Figure F-4: Data Viewer Menu



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Warranty and Service

Limited Warranty

Teledyne Princeton Instruments (“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 One (1) Year Warranty

Teledyne Princeton Instruments warrants this product against substantial defects in materials and/or workmanship for a period of up to one (1) year after shipment. During this period, Teledyne Princeton Instruments 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 Princeton Instruments 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 Princeton Instruments authorized representative/distributor for repair information and assistance, or visit our technical support page at www.princetoninstruments.com.

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

Teledyne Princeton Instruments warrants, with the exception of the CCD imaging 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 Princeton Instruments will repair or replace, at its sole option, any defective parts, without charge to you. You must deliver the entire product to the Teledyne Princeton Instruments factory or, at our option, a factory-authorized service center. You are responsible for the shipping costs to return the product to Teledyne Princeton Instruments. International customers should contact their local Teledyne Princeton Instruments representative/distributor for repair information and assistance or visit our technical support page at www.princetoninstruments.com.

XP Vacuum Chamber Limited Lifetime Warranty

Teledyne Princeton Instruments warrants that the cooling performance of the system will meet our specifications over the lifetime of an XP style detector (has all metal seals) or Teledyne Princeton Instruments will, at its sole option, repair or replace any vacuum chamber components necessary to restore the cooling performance back to the original specifications at no cost to the original purchaser. *Any failure to “cool to spec” beyond our Basic (1) year limited warranty from date of shipment, due to a non-vacuum-related component failure (e.g., any components that are electrical/electronic) is NOT covered and carries NO WARRANTIES EXPRESSED OR IMPLIED.* Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

Sealed Chamber Integrity Limited 12 Month Warranty

Teledyne Princeton Instruments warrants the sealed chamber integrity of all our products for a period of twelve (12) months after shipment. If, at anytime within twelve (12) months from the date of delivery, the detector should experience a sealed chamber failure, all parts and labor needed to restore the chamber seal will be covered by us. *Open chamber products carry NO WARRANTY TO THE CCD IMAGING DEVICE, EXPRESSED OR IMPLIED.* Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

Vacuum Integrity Limited 12 Month Warranty

Teledyne Princeton Instruments warrants the vacuum integrity of “Non-XP” style detectors (do not have all metal seals) for a period of up to twelve (12) months from the date of shipment. We warrant that the detector head will maintain the factory-set operating temperature without the requirement for customer pumping. Should the detector experience a Vacuum Integrity failure at anytime within twelve (12) months from the date of delivery all parts and labor needed to restore the vacuum integrity will be covered by us. Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

Image Intensifier Detector Limited One Year Warranty

All image intensifier products are inherently susceptible to Phosphor and/or Photocathode burn (physical damage) when exposed to high intensity light. Teledyne Princeton Instruments warrants, with the exception of image intensifier products that are found to have Phosphor and/or Photocathode burn damage (which carry NO WARRANTIES EXPRESSED OR IMPLIED,) all image intensifier products for a period of one (1) year after shipment. *Refer to additional Limited One (1) year Warranty terms and conditions above, which apply to this warranty.* Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

X-Ray Detector Limited One Year Warranty

Teledyne Princeton Instruments warrants, with the exception of CCD imaging device and fiber optic assembly damage due to X-rays (which carry NO WARRANTIES EXPRESSED OR IMPLIED,) all X-ray products for one (1) year after shipment. *Refer to additional Basic Limited One (1) year Warranty terms and conditions above, which apply to this warranty.* Responsibility for shipping charges is as described above under our Basic Limited One (1) Year Warranty.

Software Limited Warranty

Teledyne Princeton Instruments warrants all of our manufactured software discs to be free from substantial defects in materials and/or workmanship under normal use for a period of one (1) year from shipment. Teledyne Princeton Instruments 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 CDROM from our factory for an incidental shipping and handling charge. *Refer to Item 12 in [Your Responsibility](#) of this warranty for more information.*

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, the owner's manual should be consulted before contacting the Teledyne Princeton Instruments technical support staff or authorized service representative for assistance. If you have consulted the owner's manual and the problem still persists, please contact the Teledyne Princeton Instruments technical support staff or our authorized service representative. Refer to Item 12 in *Your Responsibility* of this warranty for more information.

Your Responsibility

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

1. 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 Princeton Instruments.
2. You must notify the Teledyne Princeton Instruments factory service center within (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 one (1) year limited warranty and/or any other warranty, expressed or implied.
3. All warranty service must be made by the Teledyne Princeton Instruments factory or, at our option, an authorized service center.
4. Before products or parts can be returned for service you must contact the Teledyne Princeton Instruments 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.
5. These warranties are effective only if purchased from the Teledyne Princeton Instruments factory or one of our authorized manufacturer's representatives or distributors.
6. Unless specified in the original purchase agreement, Teledyne Princeton Instruments is not responsible for installation, setup, or disassembly at the customer's location.
7. 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;
 - has been damaged as a result of misuse, improper installation, faulty or inadequate maintenance, or failure to follow instructions furnished by us;
 - has had serial numbers removed, altered, defaced, or rendered illegible;
 - has been subjected to improper or unauthorized repair;
 - has been damaged due to fire, flood, radiation, or other "acts of God," or other contingencies beyond the control of Teledyne Princeton Instruments; or
 - is a shutter which is a normal wear item and as such carries a onetime only replacement due to a failure within the original 1 year Manufacturer warranty.
8. After the warranty period has expired, you may contact the Teledyne Princeton Instruments factory or a Teledyne Princeton Instruments-authorized representative for repair information and/or extended warranty plans.
9. 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.

10. 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 Princeton Instruments' liability exceed the cost of the repair or replacement of the defective product or part.
11. This limited warranty gives you specific legal rights and you may also have other rights that may vary from state to state and from country to country. Some states and countries do not allow limitations on how long an implied warranty lasts, when an action may be brought, or the exclusion or limitation of incidental or consequential damages, so the above provisions may not apply to you.
12. When contacting us for technical support or service assistance, please refer to the Teledyne Princeton Instruments factory of purchase, contact your authorized Teledyne Princeton Instruments representative or reseller, or visit our technical support page at www.princetoninstruments.com.

Contact Information

Teledyne Princeton Instruments' manufacturing facility for this product is located at the following address:

Teledyne Princeton Instruments
3660 Quakerbridge Road
Trenton, NJ 08619 (USA)

Tel: 1-800-874-9789 / 1-609-587-9797

Fax: 1-609-587-1970

Customer Support E-mail: techsupport@princetoninstruments.com

Refer to <http://www.princetoninstruments.com/support> for complete support and contact information, including:

- Up-to-date addresses and telephone numbers;
- Software downloads;
- Product manuals;
- Support topics for Teledyne Princeton Instruments' product lines.

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