TELEDYNE PRINCETON INSTRUMENTS
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Part of the Teledyne Imaging Group

BLAZE® System Manual

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Revision History

Issue	Date	List of Changes
Issue 4	April 2, 2019	Issue 4 of this document incorporates the following changes: • Rebranded as Teledyne Princeton Instruments,
Issue 3	October 30, 2018	Issue 3 of this document incorporates the following changes: • Updated external coolant circulator information.
Issue 2	November 8, 2017	Issue 2 of this document incorporates the following changes: • Added Appendix C, Drain Coolant from BLAZE.
Issue 1	June 13, 2017	This is the initial release of this document.

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Chapter 1: About this Document

Thank you for purchasing a BLAZE 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 this 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 170 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 BLAZE system.

This document provides all information necessary to safely install, configure, and operate the BLAZE, 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 BLAZE 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
–	BLAZE Camera System Data Sheet
Varies	Spectrograph User 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, BLAZE Camera System

  This chapter provides information about the components included with a standard BLAZE 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 information about integrating the BLAZE into a user's experiment.
- Chapter 5, Hardware Configuration

  This chapter provides information about the installation and configuration of system hardware.
- Chapter 6, LightField First Light

  This chapter provides a step-by-step procedure for placing a BLAZE camera system in operation for the first time when using Teledyne Princeton Instruments' LightField 64-bit data acquisition software.
- Chapter 7, Exposure

  This chapter discusses the various 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 discusses the configuration of the Analog to Digital Conversion configuration parameters.
- Chapter 9, Full Frame Readout

  This chapter discusses Full Frame Readout operation and related parameter configuration.
- Chapter 10, Kinetics Readout

  This chapter discusses Kinetics operation and related parameter configuration.
- Chapter 11, SeNsR Readout

  This chapter discusses SeNsR operation and related parameter configuration.
- Chapter 12, Binning

  This chapter discusses the configuration of hardware and software binning.
- Chapter 13, Shutter Control

  This chapter discusses the configuration of shutter control parameters.
- Appendix A, Technical Specifications

  Provides CCD, system, and other basic specifications for a BLAZE system.
- Appendix B, Outline Drawings

  Provides outline drawings of the BLAZE camera and power supply.

- Appendix C, Drain Coolant from BLAZE
  This appendix provides information necessary to safely drain coolant from within the BLAZE camera body.
- Appendix D, Custom Modes
  Provides information necessary to configure custom chip modes on the BLAZE.
- Appendix E, Troubleshooting
  This appendix provides recommended troubleshooting information for issues which may be encountered while working with a BLAZE camera system.
- Warranty and Service
  This section provides warranty information for the BLAZE. 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 BLAZE 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 BLAZE 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 BLAZE 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 BLAZE 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 BLAZE 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 170 for complete information.

CAUTION!

If a non-Teledyne Princeton Instruments/third-party shutter is connected to a BLAZE camera without first configuring the shutter driver, the shutter may not work, and the shutter and/or the BLAZE 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 27 to a BLAZE. Refer to Contact Information on page 170 for complete contact information.

1.6.2 UV Coatings

CAUTION!

If using a camera with a UV (Lumogen or Unichrome™) coated CCD, protect it from unnecessary exposure to UV radiation. This radiation slowly bleaches the coating, reducing sensitivity.

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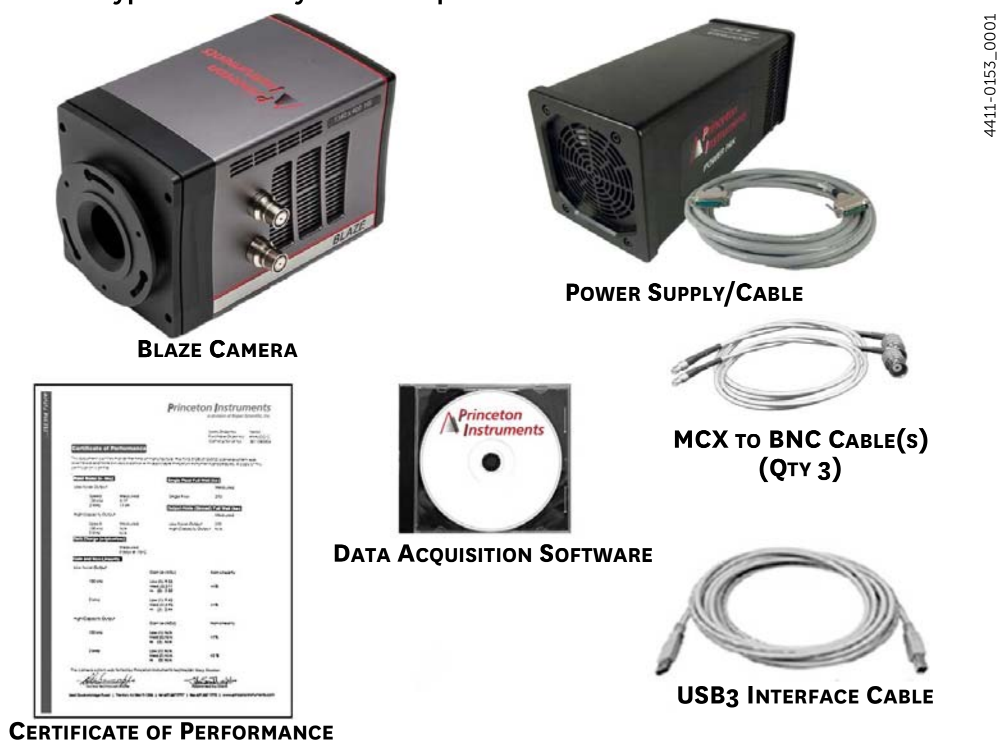
Chapter 2: BLAZE Camera System

This chapter provides an introduction to, and overview information about, Princeton Instrument's BLAZE camera system. Figure 2-1 shows those items that are typically included as part of a standard BLAZE Camera system.

Figure 2-1: Typical BLAZE System Components



Standard items for a typical air-cooled system include:

- BLAZE 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:

- BLAZE Camera;
- Power Supply and Cable;
- USB3 Interface Cable;
- MCX to BNC Adapter Cables[a];
- External Coolant Circulator[b];
- Coolant Hoses[b];
- Certificate of Performance;
- Data Acquisition Software, including Installation Disk and Hardware Key.

a. Length May Vary
b. Not illustrated in Figure 2-1.

2.1 BLAZE Camera

BLAZE represents the most advanced camera design utilizing years of experience and expertise in low-light detection. Whether an application involves Raman spectroscopy in the near infrared or semiconductor imaging in the ultraviolet, BLAZE has everything needed to tackle the most demanding applications.

BLAZE cameras, illustrated in Figure 2-2, are fully integrated camera systems. The camera contains all of the electronics necessary to read out and control the CCD device. For instance, it houses precision analog-to-digital converters (ADCs) positioned close to the CCD for lowest noise and has USB 3.0 electronics to interface with the host computer.

Figure 2-2: Typical BLAZE Cameras

4411-0153_0002

BLAZE 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.

Among the many state-of-the-art features are its maintenance-free permanent vacuum, integrated controller, deep thermoelectric air-cooling, and compact design.

2.1.1 eXcelon®

eXcelon is a CCD/EMCCD sensor technology jointly developed by Teledyne Princeton Instruments, Teledyne e2v, and Teledyne Photometrics®. Spectroscopy CCDs using this technology provide the following significant benefits:

- Improved Sensitivity

  Improved QE over broader wavelength region compared with back-illuminated sensors.
- Reduced Etaloning

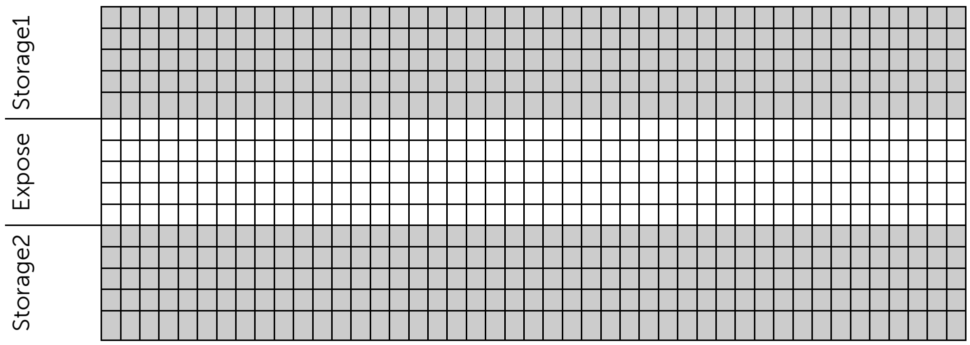
  Up to 10 times lower etaloning or unwanted fringes in near infrared (NIR) region compared with standard back-illuminated CCDs.

2.1.2 SeNsR

Teledyne Princeton Instruments' exclusive SeNsR technology provides significant Signal-to-Noise Ratio (SNR) gains for some spectrographic applications, such as sensor pump-probe experiments, in which a fluctuating background is interfering with the signal of interest.

SeNsR incorporates a CCD in which the image area has been divided into three horizontal strips in which each strip is comprised of the same number of rows. The top and bottom strips are used for temporary charge storage while the center strip is exposed to the spectrum of interest. See Figure 2-3.

Figure 2-3: Typical SeNsR CCD Row/Strip Organization



Once the center Expose strip has been exposed to Spectrum1, the pixel charge packets are shifted upward and the center Expose strip is then exposed to Spectrum2.

After the center Expose strip has been exposed to Spectrum2, the pixel charge packets are then shifted downward so that:

- The packets from Spectrum1 that had been stored in the upper strip (Storage1) are now back in the Expose strip, and
- The packets from Spectrum2 are now stored in the lower strip (Storage2.)

The center strip is once again exposed to Spectrum1 which subsequently increases the stored charge in each pixel. This Expose-Shift process continues until the programmed number of cycles has been performed, at which time the CCD is read out as usual. See Figure 2-4 for a typical 4-exposure cycle.

Figure 2-4: Typical SeNsR Expose/Shift/Readout Cycle (4 Exposures)

	Exposure/Shifts								CCD Readout
Storage1		S1		2S1		3S1		4S1	4S1
Exposure	S1	S2	2S1	2S2	3S1	3S2	4S1	4S2	4S2
Storage2			S2		2S2		3S2		

Once the CCD has been read, the spectra are then subtracted. Typically, the two acquired spectra are:

- The Spectrum of interest with the Background, and
- The background by itself.

The two spectra may also be signals that exhibit small differences between them.

In effect, SeNsR temporarily interleaves the acquired spectra so that when a background is varying slowly with respect to the shift interval, the background is essentially identical for both:

- The [Signal + Background] spectrum, and
- The Background-Only spectrum.

Therefore, when the Background-Only spectrum is subtracted from the [Signal + Background] spectrum (to a first order approximation,) the Signal-Only spectrum remains.

2.1.2.1 Advantages

The primary advantage gained by using SeNsR is the ability to substantially suppress an interfering signal that varies with time, including showing small variations in similar spectra.

It should be noted that the degree of suppression depends on the time variation of the interfering signal relative to the timing of the CCD exposure times.

Additionally:

- If the interference changes in intensity between the [Signal + Background] exposure and the Background-Only exposure, then the cancellation of the background will be less effective.
- In most, but not all, cases, the variation of the interfering background is not monotonic. Therefore, over the course of many Exposure-Shift cycles, the variations may cancel to some extent. That is, the cancellation of the background depends on the difference between the sum of the background samples in the [Signal + Background] exposures and the sum of the background samples in the Background-Only exposures.
- To track a varying background, the CCD should be operated using short exposures and a high SeNsR frequency. This requires compromising between maximizing the SeNsR frequency and the effects of clock-induced charge.

2.1.2.2 Limitations

Although SeNsR provides significant SNR gains in actual experimental applications, the CCD itself introduces some unavoidable limitations, such as:

- Pixel Well Size;
- Dark current and clock-induced charge which limit available exposure time;

  BLAZE cameras include very high performance cooling to limit dark current, so in most cases dark current will not be a major limiting factor.

  However, clock-induced charge is a concern due to the large number of clocks to which each pixel is subjected.
- Because SeNsR requires the desired light source to be turned off for half of the time, half of all available light is lost. Consequently, SeNsR provides no real advantage when the background interference is constant.
- SeNsR cannot remove shot noise that is part of the background.

2.1.3 Power

All voltages required by BLAZE camera systems are generated and delivered by an external power supply included with each BLAZE camera.

CAUTION!

Use of a power supply other than that provided with the BLAZE camera will void the camera warranty. For specific power supply requirements, contact Teledyne Princeton Instruments. Refer to Contact Information on page 170 for complete information.

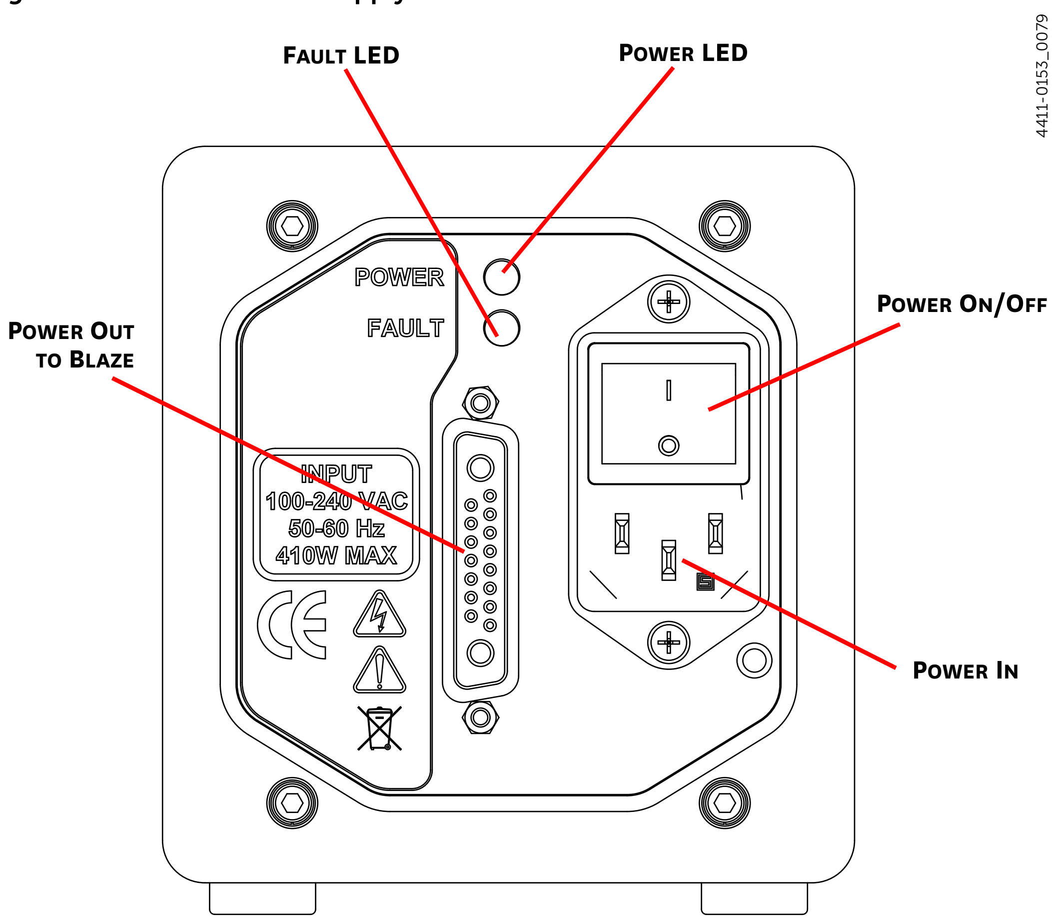
The receptacle on the power supply should be compatible with the line-voltage line cords in common use in the region to which the system is shipped. If the power supply receptacle is incompatible, a compatible adapter should be installed on the line cord, taking care to maintain the proper polarity to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

Figure 2-5 shows the connectors and indicators found on the rear of the BLAZE power supply.

REFERENCES:

Refer to Section A.3, Power Specifications, on page 147 for detailed voltage specifications.

Figure 2-5: BLAZE Power Supply Connectors and Indicators



Refer to Table 2-2 for information about each connector and indicator on the power supply.

Table 2-1: BLAZE Power Supply Connectors and Indicators

Label	Description
Power Out	Provides necessary power and signals to BLAZE.
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 E, Troubleshooting, on page 157 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. ***NOTE:*** If the Power On/Off switch is in the ON position, but the Power LED is not illuminated, refer to Section E.1.2, Power Supply Switch in On Position, But Power LED Extinguished, on page 158 for recommended troubleshooting procedures.
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.

2.1.4 CCD Arrays

The BLAZE camera system 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 BLAZE cameras, refer to Table A-2, BLAZE CCD Specifications, on page 145.

2.1.5 Cooling

Dark current is reduced in BLAZE 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 146 for specific cooling information.

2.1.5.1 Internal Fan

The BLAZE camera is equipped with an internal cooling fan that:

- Removes heat from the Peltier device that cools the CCD array, and
- Cools the electronics.

Teledyne Princeton Instruments ArcTec cooling technology cools BLAZE'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.

However, in some applications, the fan's vibration could reduce image quality. In these instances, the internal fan can be disabled on the Sensor Expander within LightField.

- When BLAZE is being 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 BLAZE monitor its temperature and will reactivate the fan before temperatures within the camera rise too much.
- When BLAZE is being 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.

2.1.5.2 External Cooling Circulator

BLAZE 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 (23ºC) water and ethylene glycol antifreeze at 1 liter per minute. Refer to Section A.5, External Coolant Circulator Specifications, on page 148 for additional information. If desired, contact Teledyne Princeton Instruments for additional recommendations. Refer to Contact Information on page 170 for complete information.

CAUTION!

Never set the 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 BLAZE monitors its internal temperature and will automatically restart its fan regardless of the software settings if it senses excessive internal heat buildup.

2.1.5.3 Coolant Ports

BLAZE 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 circulator and the laboratory atmosphere.

WARNING!

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

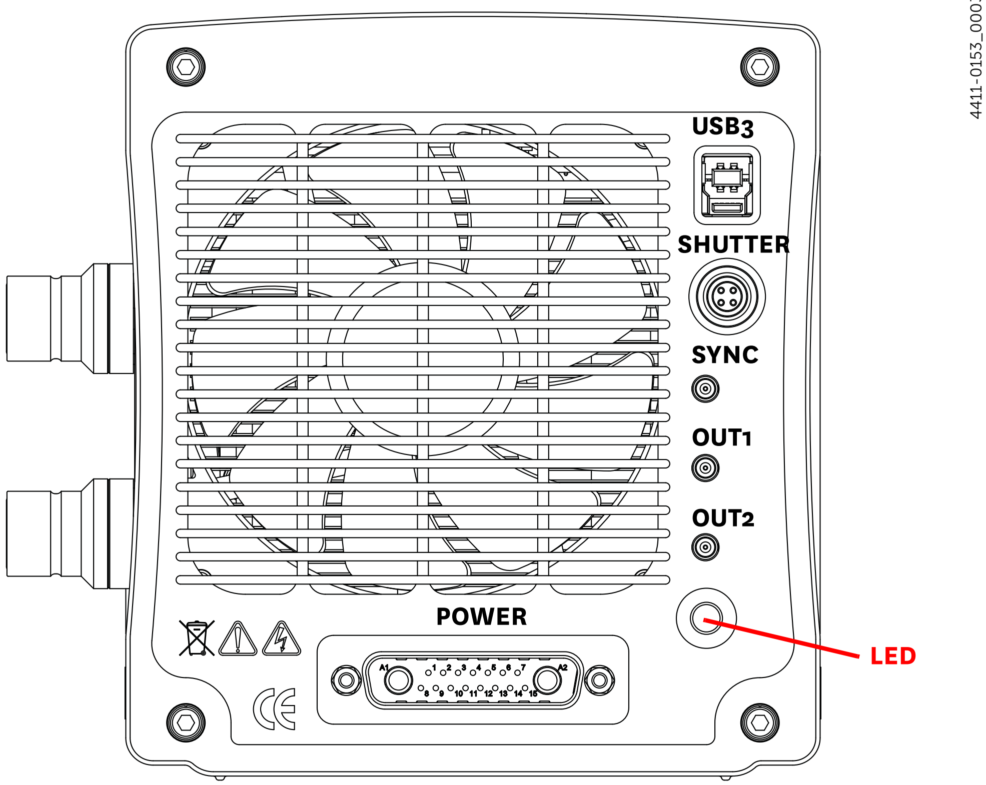
CAUTION!

The wetted areas of the BLAZE heat exchanger and fittings are nickel plated.

2.1.6 Rear-Panel Connectors and Indicators

Figure 2-6 illustrates the rear-panel connectors and indicators on a BLAZE camera.

Figure 2-6: BLAZE Rear-Panel Connectors and Indicators



Refer to Table 2-2 for information about each rear-panel connector and indicator.

Table 2-2: BLAZE Rear-Panel Connectors and Indicators (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. ***NOTE:*** Refer to Section 13.4, Using an External Shutter, on page 141 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 kΩ 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} or less than 0 V_{DC} (i.e., a negative voltage,) to this input. Doing so may permanently damage the BLAZE 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.
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.

Table 2-2: BLAZE Rear-Panel Connectors and Indicators (Sheet 2 of 2)

Label	Description
POWER	Power input from external power supply provided with the BLAZE system
LED[a]	Upon initial power up, this LED flashes one time at full illumination. The LED remains dimly illuminated while waiting for an incoming trigger. The reduced illumination is to prevent stray light from contaminating acquired experimental data. When an incoming trigger is detected, the LED then flashes at a slightly increased illumination level, but still at a level that will not contaminate experimental data.

a. Not labeled on BLAZE chassis.

2.2 Cables

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

Table 2-3: Standard BLAZE Camera System Cables

Cable	Part Number	Description/Purpose	Length
Power Cable	6050-0714	Primary power cable connecting the BLAZE to the external power supply. See Figure 2-6.  4411-0153_0102	3 m [9.8 ft]
	6050-0715[a]		5 m [16.4 ft]
USB 3	6050-0733	Connects the USB 3 connector on the rear of the BLAZE with a USB card installed in the host computer.  4411-0153_0004	3 m [9.8 ft]
MCX to BNC	6050-0540	Three (3) MCX to BNC adapter cables are included. These connect to the EXT SYNC and the LOGIC OUT connectors on the rear of the BLAZE.  4411-0153_0005	Varies

a. Optional. Contact Teledyne Princeton Instruments for ordering information. Refer to Contact Information on page 170 for complete information.

2.3 Certificate of Performance

Each BLAZE 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 BLAZE 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 BLAZE camera systems, including:

- LightField®

  The BLAZE 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 PICam Programmer's Manual for the list of supported operating systems.
- 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:

BLAZE 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 BLAZE. 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, BLAZE cameras. Refer to Table 2-4 for the list of external shutters that are supported by BLAZE.

CAUTION!

In order to prevent potential permanent damage to either the BLAZE 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 BLAZE. Refer to Contact Information on page 170 for complete information.

NOTE:

BLAZE is capable of very high frame rates, particularly in spectroscopic modes. These external shutters will wear out very quickly if attempting to operate them at high frame rates for extended periods. LightField does not prevent users from attempting to run at very high frame rates. In some cases, the user may need to operate at high frame rates for short bursts and/or consider the shutter to be a consumable.

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

REFERENCES:

Refer to Table A-7, BLAZE External Shutter Specifications, on page 149 for technical specifications for each supported shutter.

Contact Teledyne Princeton Instruments for information about ordering an external shutter for use with BLAZE. Refer to Contact Information on page 170 for complete information.

2.6 Unpack the System

All required items should be included with the shipment. The BLAZE 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 BLAZE 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 170 for complete information.

2.6.1 Verify Equipment and Parts Inventory

Verify all equipment and parts required to set up the BLAZE system have been delivered.

A typical system consists of:

- BLAZE 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

Accessories that may have been purchased include:

- External Shutter(s);
- External Coolant Circulator and hoses (for liquid-cooled system).

2.7 BLAZE Camera and System Maintenance

WARNING!
Turn off all power to the equipment and secure all covers before cleaning the units. 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 BLAZE 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 Optical Surfaces

As a good practice, the camera must be closed/capped off with the supplied dust cover or lens cap when not in use. If it becomes necessary to clean the optical window due to the accumulation of atmospheric dust, we advise that the drag-wipe technique be used. This involves dipping a clean cellulose lens tissue into clean anhydrous methanol, and then dragging the dampened tissue over the optical surface to be cleaned. Do not allow any other material to touch the optical surfaces.

2.7.3 Repairs

Because the BLAZE 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 170 for complete information.

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

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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 BLAZE 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

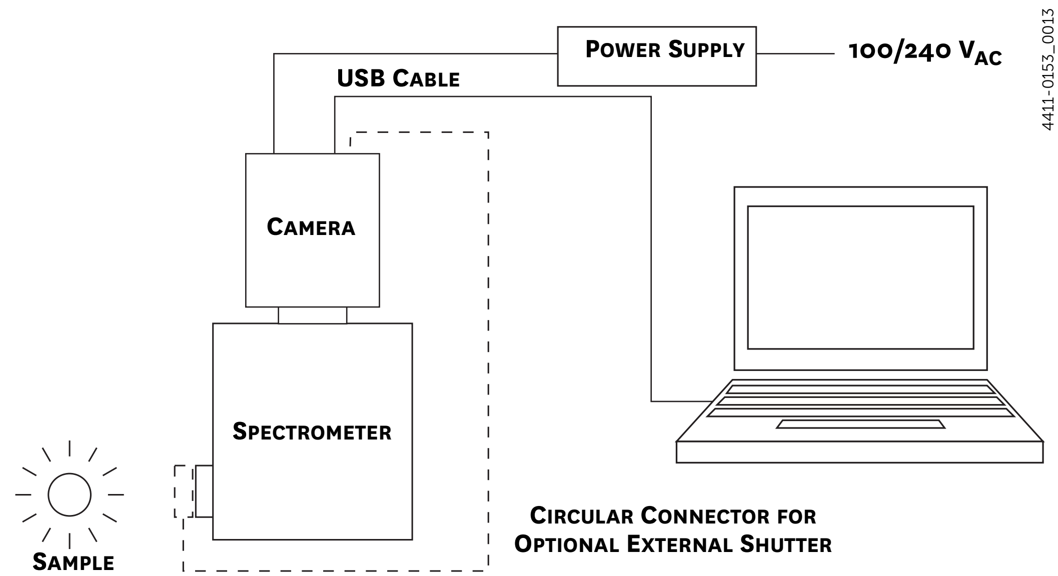
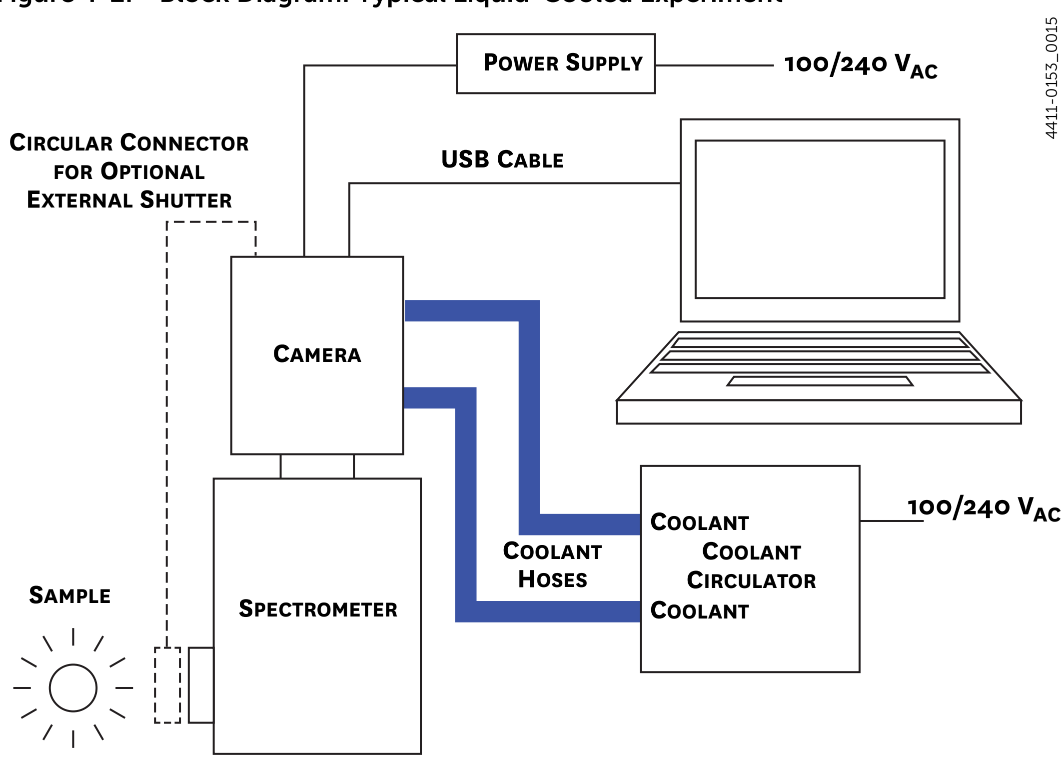


Figure 4-2: Block Diagram: Typical Liquid-Cooled Experiment



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Chapter 5: Hardware Configuration

This chapter provides information about the installation of hardware that may be installed on a BLAZE camera.

A BLAZE camera must be properly mounted to a spectrograph in order to focus the optics. Additional precautions must also be taken to prevent overexposure of the camera.

The distance to the focal plane from the front of the mechanical assembly depends on the specific configuration. Refer to Section A.6, Shutter Specifications, on page 149, for complete information.

5.1 Spectrograph Adapters

Teledyne Princeton Instruments offers a number of adapters for mounting a BLAZE camera onto a spectrograph, including:

- Teledyne Acton Research Series Spectrographs, and
- IsoPlane Family of Spectrographs.

NOTE:

Other adapters may be available. Contact Teledyne Princeton Instruments for specific information. Refer to Contact Information on page 170, for complete contact information.

Refer to Table 5-1 for information about the appropriate installation procedure.

Table 5-1: Spectrograph Adapter Installation Procedures

Spectrograph	BLAZE Configuration	Proceed to…
Teledyne Acton Research Series	Flange	page 36
IsoPlane Family	Flange	page 37

5.1.1 Teledyne Acton Research Series Spectrograph

Figure 5-1: Installing a Typical Teledyne Acton Research Series Spectrograph Adapter

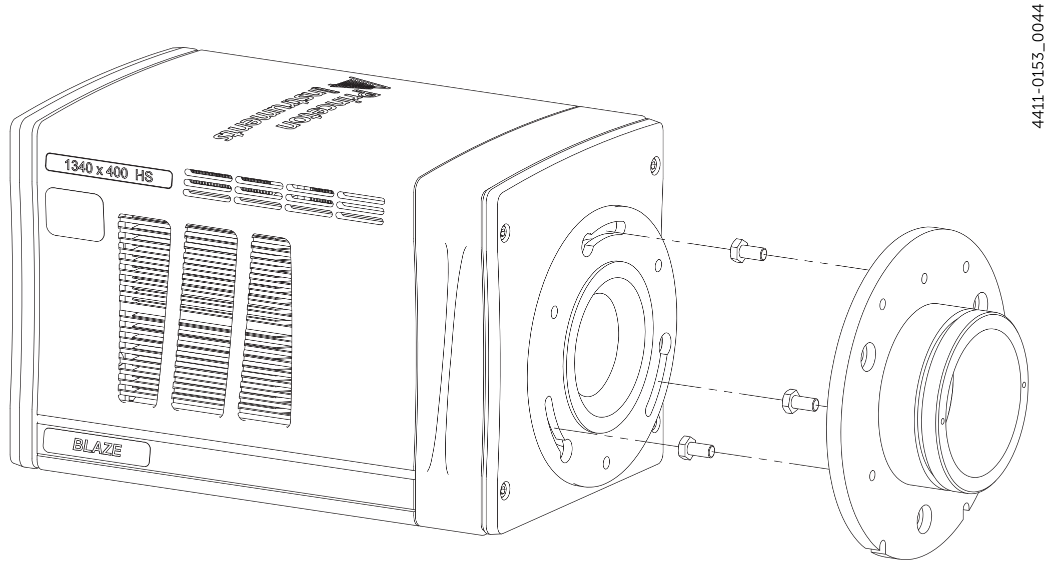


Table 5-2: Required Items

Quantity	Part Number	Description
3	2826-0135	Screw, 10-32 x 0.375, Hex Head, Stainless Steel

5.1.1.1 Installation Procedure

Perform the following procedure to install an Teledyne Acton Research Series Spectrograph adapter:

1. Verify that the shipping cover has been removed from the detector port on the spectrograph.
2. If the spacer plate has been removed, reinstall it on the sliding tube.
3. Screw the three (3) hex head screws into the sliding tube, leaving ¼″ of thread exposed.
4. Mount the detector flange on the sliding tube assembly and rotate the detector so the screw heads are over the narrow end of the slots.
5. Tighten the screws.

NOTE:

Adapter parts are machined to provide a tight fit. If you need to remove the sliding tube from the spectrograph, first loosen the two setscrews that secure it, and then rotate the tube as you pull it out. If you have removed the sliding tube from the spectrograph, rotate the sliding tube as you re-insert it, and tighten the setscrews afterwards to secure it. Forcing the tube into the spectrograph could permanently damage the tube and the spectrograph opening.

5.1.2 IsoPlane SCT-320

Figure 5-2: Installing an IsoPlane SCT-320 Adapter

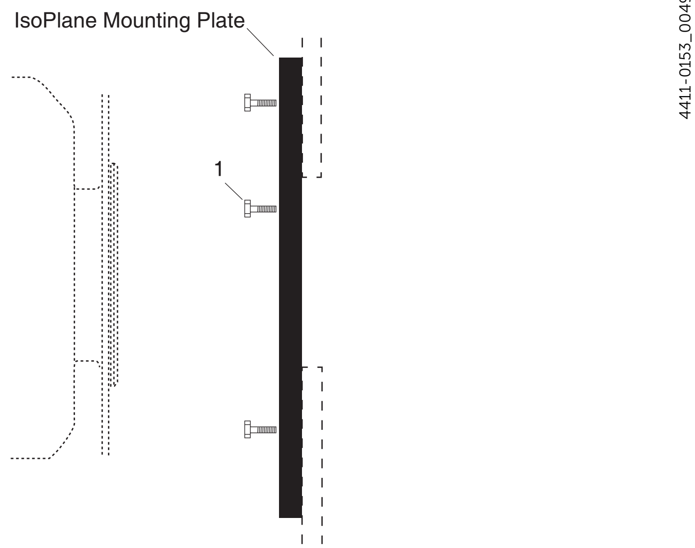


Table 5-3: Required Items

Quantity	Part Number	Description
1	2826-0120	Screw, 10-32 x 1/2, Hex Head, Stainless Steel

5.1.2.1 Installation Procedure

Perform the following procedure to install this adapter:

1. Verify the shipping cover has been removed from the detector mounting plate on the IsoPlane.
2. Screw the three (3) hex head screws into the sliding tube, leaving ¼″ of thread exposed.
3. Mount the detector to the mounting plate: the text should be right-reading on the back of the detector.
4. Tighten the three screws with a 5/16″ open end wrench.

NOTES:

1. Rotational alignment of the detector to the spectrograph optics is done by loosening and subsequently tightening the screws at the mounting plate corners. The holes are slotted to allow about 4° of rotation.
2. If the IsoPlane was ordered with an internal shutter at the entrance slit, the BLAZE, when connected to the Shutter input on the IsoPlane, can control that shutter. Refer to the IsoPlane SCT 320 manual for shutter removal instructions.

5.2 External Shutter

CAUTION!

In order to prevent potential permanent damage to either the BLAZE 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 27 to a BLAZE. Refer to Contact Information on page 170 for complete information.

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

5.3 Overexposure Protection

Cameras that are exposed to room light or other continuous light sources will quickly become saturated. This most often occurs when operating without a shutter or with the shutter locked open. When BLAZE is mounted to a spectrograph, always close the entrance slit of the spectrograph to reduce the incident light.

NOTE:

If the CCD is cooled to low temperatures (below -50°C), exposure to ambient light will over-saturate it. This may increase dark charge significantly. If the camera shows elevated dark charge, it may be necessary to bring the camera back to room temperature to restore dark charge to its original level.

5.4 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 BLAZE 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 BLAZE 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 BLAZE.

   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 BLAZE 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 BLAZE voids the warranty.
4. Verify that the reservoir on the external coolant circulator contains sufficient coolant as specified by it manufacturer. If additional coolant is required, use a 50:50 mixture of water and ethylene glycol based commercial antifreeze 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.

5.4.1 Experiment Shutdown

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

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

WARNING!
If the BLAZE is to be shipped, to avoid potential catastrophic damage to the camera, all coolant must be drained from it. Refer to Appendix C, Drain Coolant from BLAZE, on page 153.

Chapter 6: LightField First Light

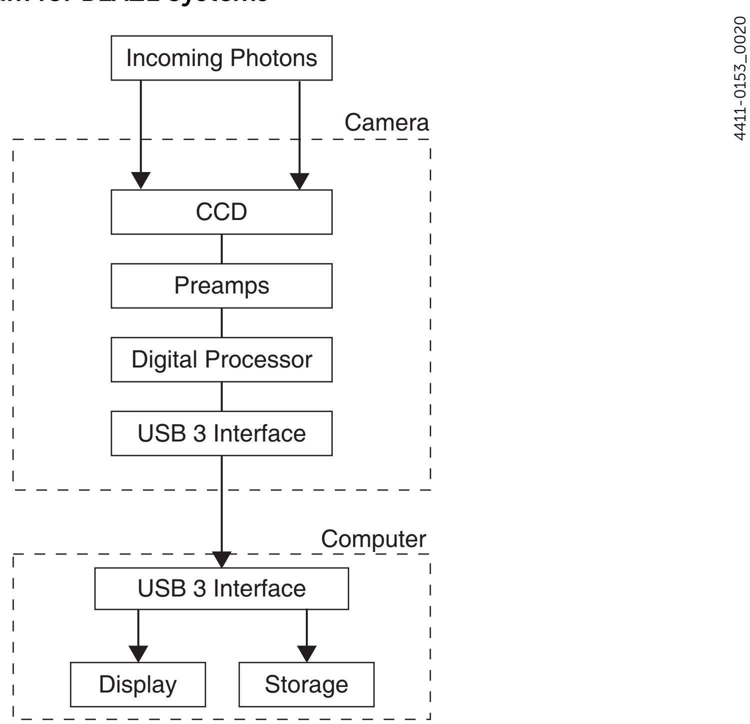
Once the BLAZE camera has been configured as described in Chapter 5, Hardware Configuration, acquiring data using LightField is straightforward. For most applications, simply:

- Establish optimum performance using Preview mode;
- Set a target camera temperature;
- Wait until the system's temperature has stabilized;
- Acquire live data in Acquire mode.

Additional considerations regarding experiment setup and equipment configuration are addressed in the LightField Online Help.

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 then transferred to the host computer. Upon data transfer, the data are displayed and/or stored via the application software. This sequence is illustrated by the block diagram shown in Figure 6-1.

Figure 6-1: Block Diagram for BLAZE Systems



Whether or not the data are displayed and/or stored depends on the data collection operation that has been selected in the application software:

- Preview

  Data collection operations use the Experiment Setup parameters to establish the exposure time (the period when signal of interest is allowed to accumulate on the CCD). Preview is typically used when setting up the system

  In Preview mode, the number of frames is ignored. A single frame is acquired and displayed, another frame is acquired which overwrites the currently displayed data, and so on, until Stop is selected.

  NOTE:

  The last frame acquired before Stop is selected cannot be stored.

  However, the last frame of data can be saved by configuring the Number of Frames to 1 and clicking Acquire rather than Stop.

  Preview mode is particularly convenient for familiarization and configuration. For ease in focusing, the screen refresh rate should be as quick as possible, achieved by operating with axes and cross-sections off, and with Zoom 1:1 selected.

- Acquire

  Acquire mode is typically used for the collection and storage of data. In Acquire mode, every frame of data collected can be automatically stored, so the completed dataset may include multiple frames with one or more accumulations. This mode is typically selected during actual data collection.

  One limitation of Acquire mode operation is that if data acquisition continues at too fast a rate for it to be stored, data overflow may occur. If this happens, try the following to remedy the situation:

  — Shut down any other programs that may be running and utilizing resources;

  — Decrease the camera speed;

  — Use a faster host computer.

6.1 Set Up and Configuration

This section provides step-by-step instructions for acquiring a spectrum in LightField for the first time. The intent of this procedure is to gain familiarity with the operation of the system and to show that it is functioning properly. Once basic familiarity has been established, additional, more complex configurations can be implemented.

The following procedure assumes:

- The system has been set up in accordance with the instructions in previous chapters;
- Familiarity with LightField;

  If this is not the case, refer to the online help while performing this procedure.
- The system includes an external shutter that is being controlled by BLAZE via the SHUTTER connector;
- A suitable light source (e.g., mercury pen-ray lamp,) has been mounted in front of the entrance slit of the spectrograph.

  Any light source with line output can be used. Standard fluorescent overhead lamps have good calibration lines as well. If there are no line sources available, it is possible to use a broadband source such as tungsten for the alignment. If this is the case, use a wavelength setting of 0.0 nm for alignment purposes.

CAUTION!

Overexposure Protection: Cameras that are exposed to room light or other continuous light sources will quickly become saturated. If the camera is mounted to a spectrograph, close the entrance slit of the spectrograph to 20 μm (typical) to reduce the incident light.

Perform the following procedure to set up and configure the system to acquire a spectrum:

1. Set the spectrograph entrance slit width to minimum (20 μm if possible.)
2. Turn ON the spectrograph (if applicable.)
3. Mount a light source such as a Teledyne Princeton Instruments IntelliCal™ Hg/Ne-Ar Dual Switchable light source in front of the entrance slit.
4. Connect the shutter cable from the external shutter into the BLAZE SHUTTER connector.

CAUTION!

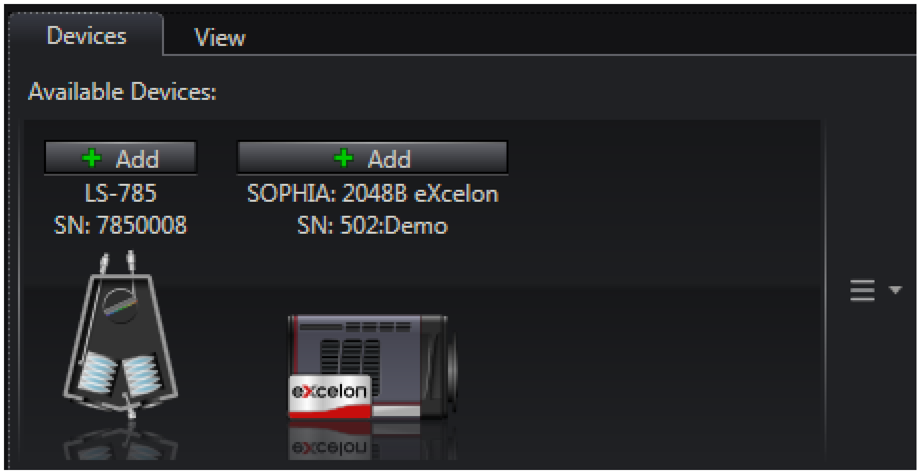
In order to prevent potential permanent damage to either the BLAZE camera and/or the shutter, always contact Teledyne Princeton Instruments before connecting an external shutter that is not listed in Table 2-4, Supported External Shutters, on page 27 to a BLAZE. Refer to Contact Information on page 170 for complete information.

NOTE:

External shutters must be equipped with a compatible shutter connector in order to mate with the external SHUTTER connector on the rear of the BLAZE camera (see Figure 2-6 on page 24). Refer to Section A.6.1, SHUTTER Connector, on page 149 for complete information.

5. Power on the camera.
6. Turn on the host computer power.
7. Launch LightField.
8. Once LightField has started, a BLAZE camera icon, as well as a spectrograph icon, will be shown in the Available Devices area. See Figure 6-2.

Figure 6-2: Typical Available Devices Area

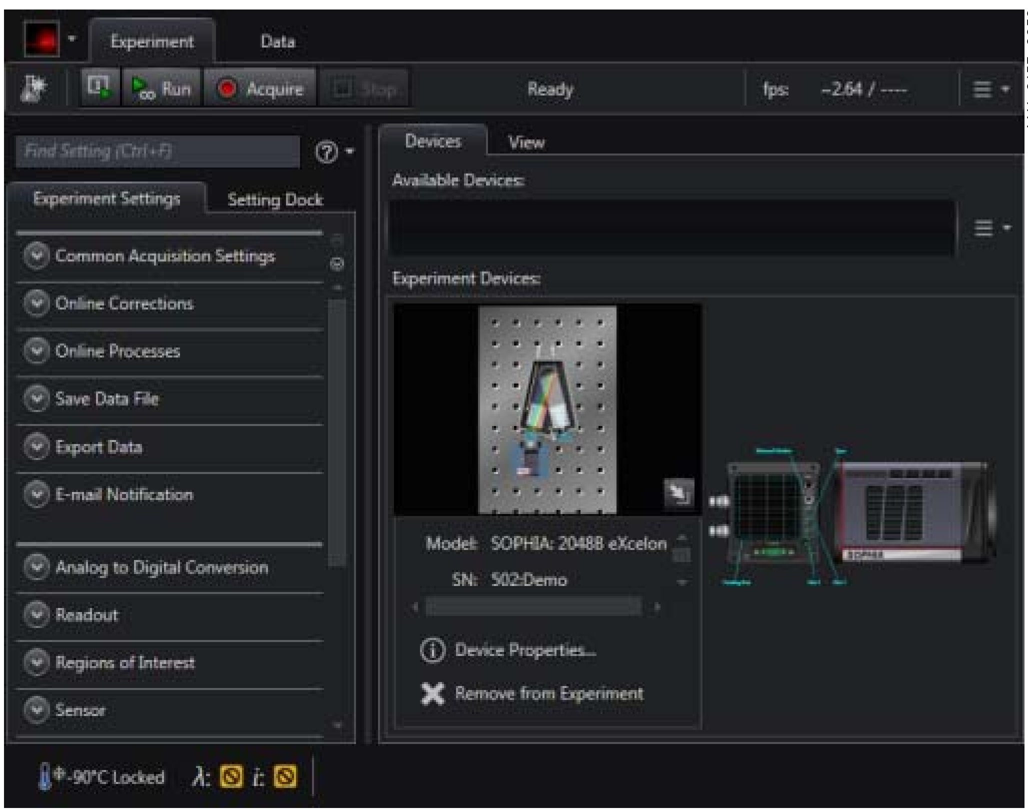


4411-0153_0051

9. Drag these two icons into the Experiment Devices area.

   The Experiment Settings stack on the left includes several expanders. Since this is a new experiment, the default configuration settings for the camera are used. See Figure 6-3.

Figure 6-3: Experiment Devices Area



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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 BLAZE 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 regions may occur.

10. On the Shutter expander, select Shutter Mode: Normal.
11. Open the Spectrometer expander and select the appropriate grating.

    In this case, the 300g/mm (Blaze: 750) grating was selected and the center wavelength was set to 500 nm for a mercury lamp. Use 0.0 nm if using a broadband source.

    NOTE:

    Overhead fluorescent lights produce a mercury spectrum. Use a white card tilted at 45 degrees in front of the entrance slit to reflect overhead light into the spectrograph. Select 500 nm as the spectral line.

12. Turn on the light source at the spectrograph's entrance slit.
13. Click Run to begin previewing the data.

    Depending on the display settings, you should see either a spectral band (image) or a graph. Background noise will decrease as the camera cools to its default temperature.
14. Turn off the light source. The data display should change to a background noise pattern or low intensity graph.

    If this occurs you have confirmed that light entering the spectrograph is being seen by the camera. Proceed to Section 6.1.1, Rotational Alignment and Focus, on page 47.

15. If there is little or no difference between the data displayed when the light source is on or off:
    a. Verify that the light source has power and is turned on.
    b. Verify that the entrance slit is open at least 10 μm.
    c. Check the Exposure Time (Common Acquisition Settings expander).
    d. Confirm that Shutter Mode is set to Normal (Shutter expander).
    e. Check the shutter cable connections.
    f. Verify shutter operation. You should hear the shutter open and close while Run is active.
        - If you hear a shutter operating and you have performed step a through step e, turn the light source on, wait a minute and then turn the light off while viewing the data display.

          If the problem is fixed, stop acquisition or proceed to Section 6.1.1, Rotational Alignment and Focus, on page 47.

          Otherwise, stop data acquisition and proceed to step g.
        - If you do not hear a shutter operating and step a through step e have been performed, stop data acquisition and proceed to step g.
    g. Verify the spectrograph has an entrance slit shutter. An externally mounted shutter is easily confirmed. Verifying an internally mounted shutter requires access to the inside of the spectrograph: refer to the spectrograph manual for instructions.
16. For additional assistance, contact Customer Support. Refer to Contact Information on page 170 for complete information.

6.1.1 Rotational Alignment and Focus

The camera mounting hardware provides two degrees of freedom:

- Rotation
  Rotation is the physical rotation of a camera while watching a live display on the monitor until spectral lines are perpendicular to the rows on the array.
- Focus
  Focus is the process of moving the camera back and forth through the spectrograph's focal plane while watching a live display until the optimal focus is achieved.

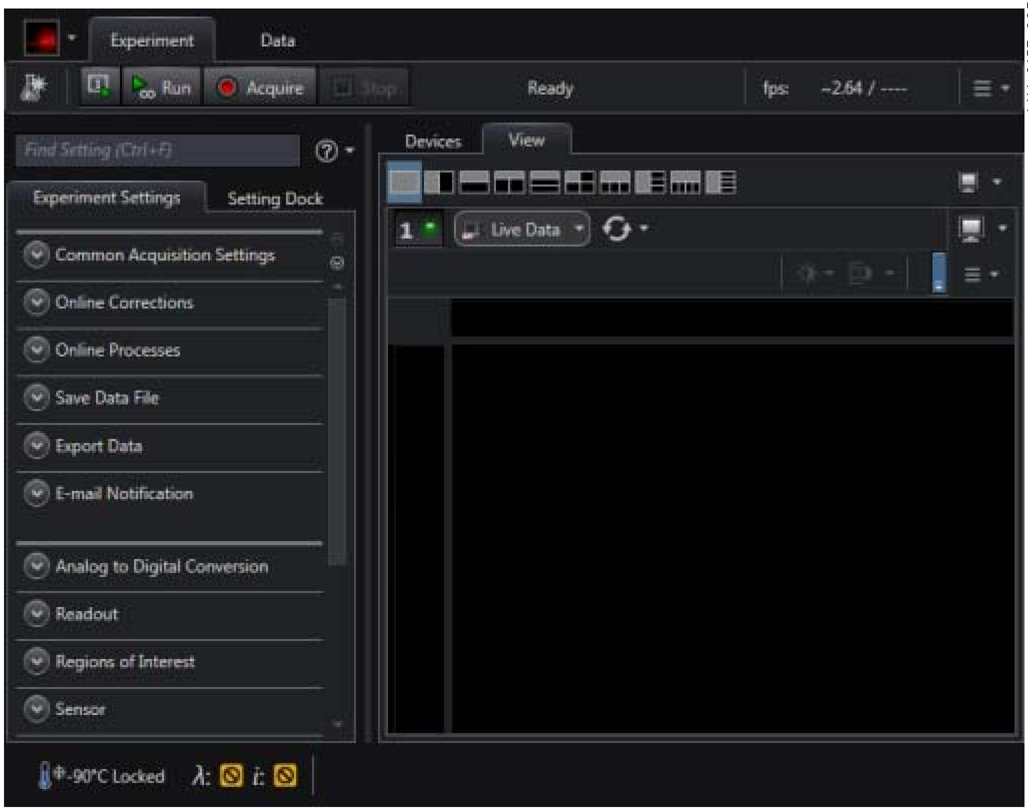
Procedures included in this section assume that the BLAZE camera and corresponding spectrograph have already been turned on and their icons have been dragged into the Experiment Devices area as shown in Figure 6-3.

6.1.1.1 Teledyne Acton Research Series Spectrograph

Perform the following procedure to rotationally align and focus the BLAZE system with an Teledyne Acton Research Series spectrograph:

1. Click on the View tab, just above Experiment Devices, to change to the display area. See Figure 6-4.

Figure 6-4: View Area



4411-0153_0053

2. Mount a light source such as a mercury pen-ray type in front of the entrance slit of the spectrograph. Any light source with line output can be used. Standard fluorescent overhead lamps have good calibration lines as well. If there are no line sources available, it is possible to use a broadband source such as tungsten for the alignment. If this is the case, use a wavelength setting of 0.0 nm for alignment purposes.

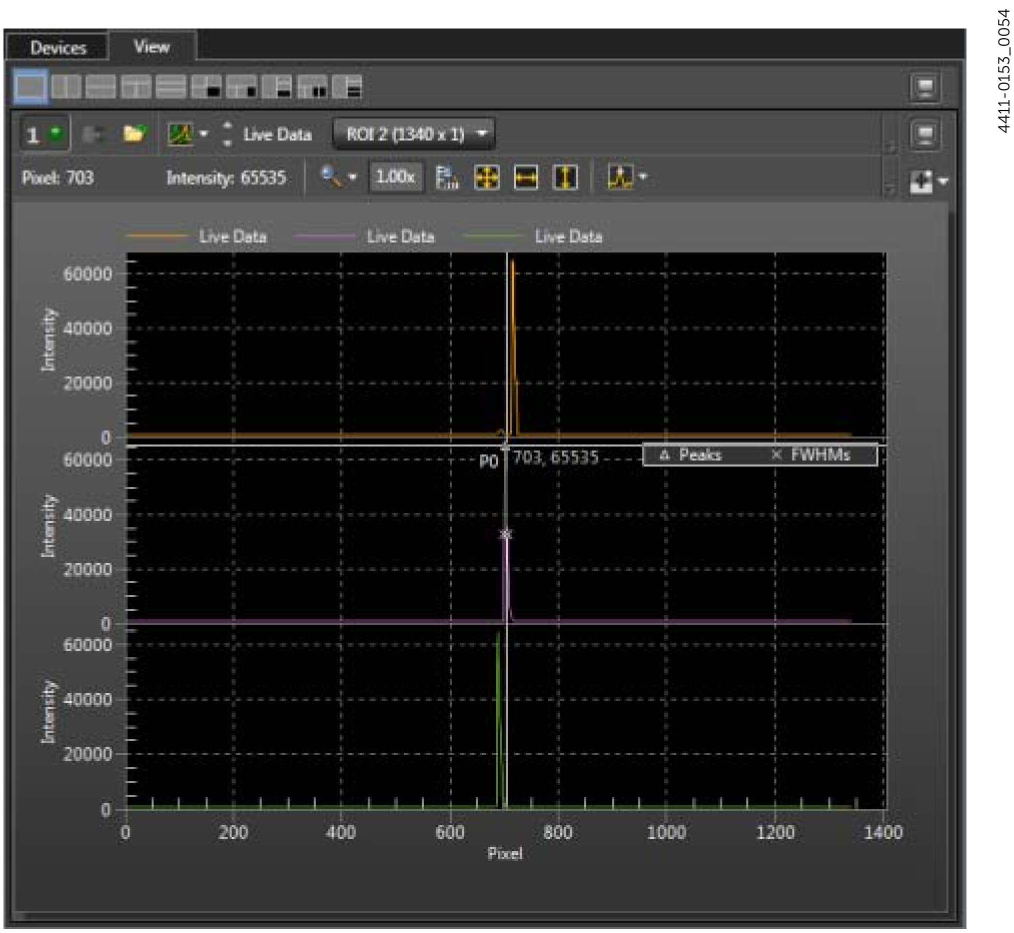
3. Open the Spectrometer expander, select the grating and set the center wavelength to 500 nm if using a mercury lamp or to 0.0 nm if using a broadband source.

NOTE:

Overhead fluorescent lights produce a mercury spectrum. Use a white card tilted at 45 degrees in front of the entrance slit to reflect overhead light into the spectrograph. Select 500 nm as the spectral line.

4. Set the slit to 10 μm. If necessary, adjust the Exposure Time to maintain optimum (near full-scale) signal intensity.
5. Wait until the detector temperature locks at its default temperature.
6. Make sure that the spectroscopy-mount adapter moves freely at the spectrograph.
7. Select Align Spectrometer... from the Experiment Options menu. Review the displayed information and then click on the Begin button. Typically, this feature creates three 1-row high ROIs (one near the top of the array, one in the middle, and one near the bottom) and begins data acquisition, as illustrated in Figure 6-5. Data will be continuously acquired and displayed but will not be stored.

Figure 6-5: Spectrometer Alignment: Before Rotational Alignment



8. Slowly move the camera in and out of focus. You should see the spectral line go from broad to narrow and back to broad. Leave the camera set for the narrowest achievable line. Note that the Peak Finding function is active for the center graph to allow you to monitor the FWHM information to achieve the narrowest line width.

   The way focusing is accomplished depends on the spectrograph, as follows:

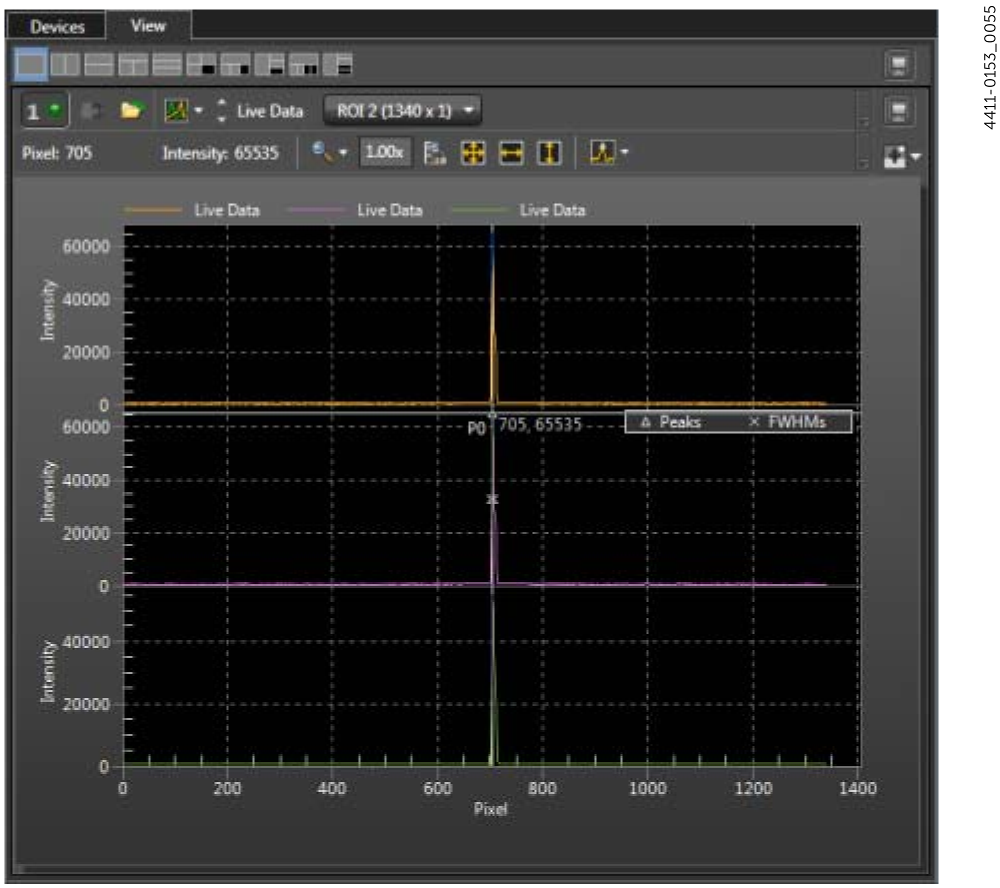
   - Long focal-length spectrographs such as the Teledyne Acton Research SP-2300

     The mounting adapter includes a tube that slides inside another tube to move the camera in or out as required to achieve optimum focus.
   - Short focal-length spectrographs

     There is generally a focusing mechanism on the spectrograph itself which, when adjusted, will move the optics as required to achieve proper focus.
   - No focusing adjustment

     If there is no focusing adjustment, either provided by the spectrograph or by the mounting hardware, then either use do-it-yourself shims, or adjust the spectrograph's focusing mirror.
9. Next adjust the rotation. This is achieved by rotating the camera while watching a live display of the line (you may need to loosen two setscrews securing the spectrograph adapter.) Click on the peak you want to monitor during the rotational alignment. This positions the large cursor to provide a vertical reference line across all of the ROIs.
10. Rotate the camera while watching the live display of the lines until the selected peak is aligned horizontally in all of the ROIs. Tighten the setscrews securing the spectrograph adapter at the spectrograph.

Figure 6-6: Spectrometer Alignment: After Rotational Alignment



Alternatively, take an image, display the horizontal and vertical cursor bars, and compare the vertical bar to the line shape on the screen. Rotate the detector until the line shape on the screen is parallel with the vertical bar.

NOTE:

When aligning other accessories, such as fibers, lenses, optical fiber adapters, first align the spectrograph to the slit. Then align the accessory without disturbing the camera position. The procedure is identical to that used to focus the spectrograph (i.e., do the focus and alignment operations while watching a live image).

11. Tighten the spectrograph set screws to secure the spectrograph adapter and stop data acquisition.

6.1.1.2 IsoPlane SCT-320 Spectrograph

Because the BLAZE is mounted directly to the mounting plate on the IsoPlane, the rotational alignment and focusing operations differ from the way they are achieved for an Teledyne Acton Research Series spectrograph. The following information assumes familiarity with the locations of the mounting plate, Micrometer Compartment, and the locking set screw. If not, refer to the IsoPlane manual supplied with the spectrograph.

This procedure assumes:

- The camera and IsoPlane have already been connected and turned on;
- LightField has been launched;
- The camera and IsoPlane icons have been placed into the Experiment Devices area;

NOTE:

Once the initial alignment and focus has been achieved, it is recommended that the process be repeated to fine-tune the alignment.

Perform the following procedure to rotationally align and focus the BLAZE system with an IsoPlane-320 spectrograph:

1. Mount an light source such as a Teledyne Princeton Instruments HG/NeAr Dual Switchable light source in front of the entrance slit.
2. Set the spectrograph to:
   - 507.3 nm if using a mercury source;
   - 0.0 nm if using a broadband source.
3. Wait for the camera to lock at the default temperature.
4. Use a 9/64” hex wrench to loosen the four screws at the corners of the camera mounting plate.
5. Select the Align Spectrometer function from the Experiment menu to open the Spectrometer Alignment dialog. This dialog describes the changes that LightField will make to the current setup to assist you in performing rotational alignment of the array to the spectrograph's optics. When the Begin button is clicked, the modifications are made and continuous live data will be displayed as you rotate the camera.
6. Click on the peak being monitored for the alignment. This will display the data cursor that you can position at the top of the peak. Since the data cursor spans the ROIs, you can use the data cursor as your vertical reference.

7. Slowly rotate the camera until the peaks align in all of the ROIs.

   Alternatively, you can acquire an image, display the large data cursor, and compare the vertical bar to the line shape on the screen. Rotate the camera until the line shape on the screen is parallel with the vertical bar.
8. After completing the rotational alignment, click on the Stop button.
9. Re-tighten the four mounting plate screws.
10. Next, remove the cover from the Micrometer Compartment.
11. Using a 3/32" hex wrench, loosen the locking set screw.
12. Click on Run, and while continuously acquiring data, adjust the micrometer until you maximize the intensity level and minimize the FWHM of a selected peak or peaks. You may want to use the Peak Find function to identify peaks and display FWHM widths.
13. Tighten down the locking set screw.
14. Place the Micrometer Cover on the spectrograph. Replace and tighten all of the cover screws.
15. Stop acquisition.

6.1.2 Data Acquisition

Perform the following procedure to acquire live data:

1. After the system has been focused, stop running in Alignment mode.
2. Make any required changes to the experiment setup and software parameters.

   Changes may include:
   - Adjusting the exposure time;
   - Setting up an entrance slit shutter;
   - Changing the timing mode to External Sync;
   - Lowering the temperature.
3. Begin running Acquire mode. Data will be acquired and displayed/stored based on the experiment settings.
4. Once data acquisition is complete, either:
   - Leave the camera power on so the array temperature will remain locked for subsequent data acquisition;
   - Shut down the system. Refer to Section 6.2, System Shutdown, for proper shutdown procedures.

6.2 System Shutdown

Perform the following procedure to shutdown the BLAZE system:

1. Set the camera's temperature to 0 °C and allow it to come to temperature.
2. Exit LightField.
3. Turn off the light source.
4. Turn off the spectrograph.
5. Turn off the camera power.

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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.

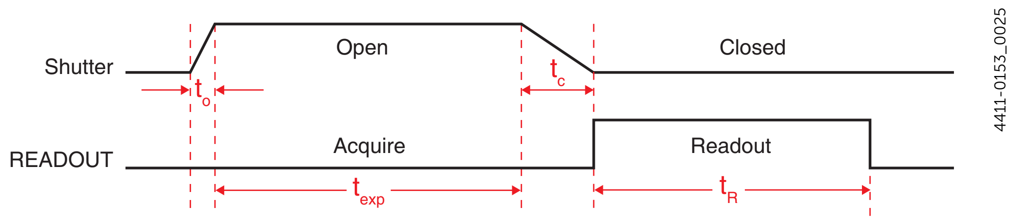
In combination with triggers these commands control when continuous cleaning of the CCD stops and when the accumulated signal will be read out.

Cleaning prevents 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.)

BLAZE requires an external shutter in order to control exposure of its CCD. Figure 7-1 illustrates how the exposure period is measured. The Reading Out signal at the OUT 1 and OUT 2 connectors on the back of the BLAZE 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



where:

- t_o is the shutter opening compensation time;

  This value is automatically configured for BLAZE.
- 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.

CAUTION!

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 generally enhances the quality of an acquired signal. Temperature control is configured 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°C of the programmed setpoint, Locked is displayed to the right of the target temperature in LightField's status bar. At this point, BLAZE's control loop will continue to reduce the thermal error, typically holding the temperature to within $\pm$0.05°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 approximately 20 minutes after thermal loop locks. However, as long as BLAZE'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 BLAZE be permitted to cool for a longer period of time before acquiring live data.

The deepest operating temperature for a system depends on the CCD array size and packaging. Refer to Table A-3, Default Operating Temperature on page 146 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 170 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 mean square 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 ~$1.414\sqrt{N_R}$, which is an increase of ~41% over the baseline readout noise. This value is calculated as follows:

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

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, BLAZE supports Clean Until Trigger (CUT,) an additional level of cleaning/removing accumulated dark charge that continues until the moment the External Sync pulse is received.

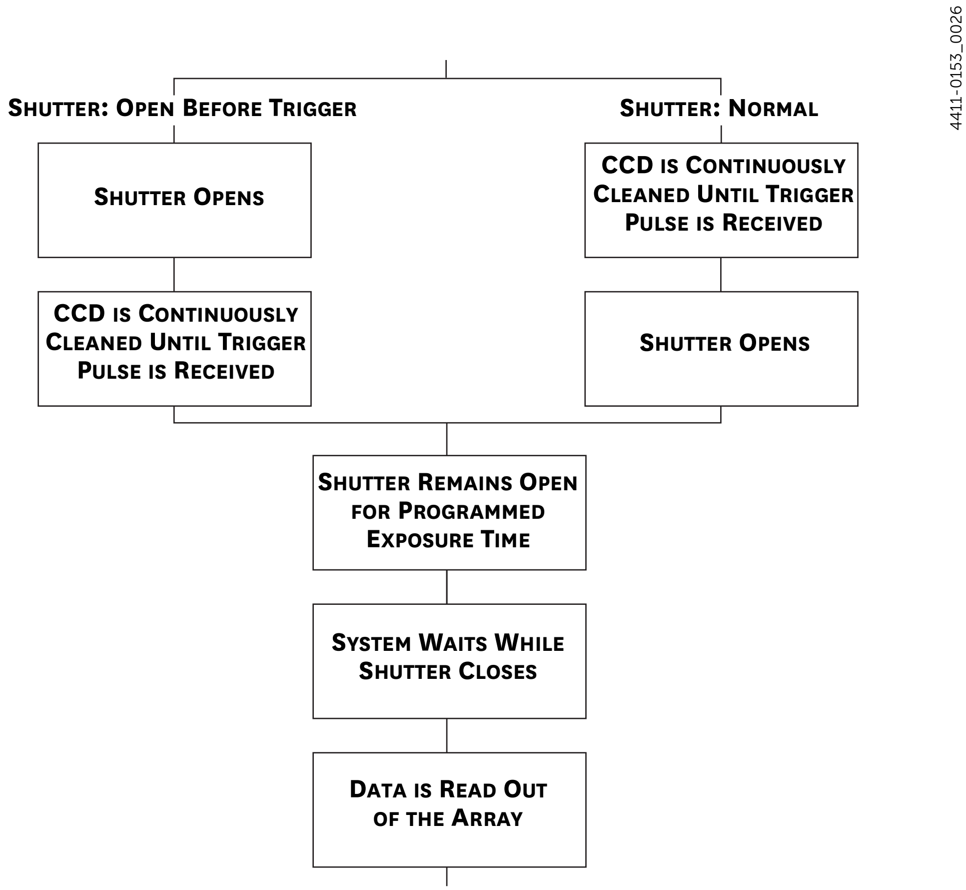
REFERENCES:

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

- Section 9.2, Experiment Timing, on page 72, for Full Frame Mode;
- Section 10.2, Experiment Timing, on page 89, for Kinetic Mode.

Figure 7-2 illustrates a flowchart of this mode.

Figure 7-2: Flowchart: Clean Until Trigger

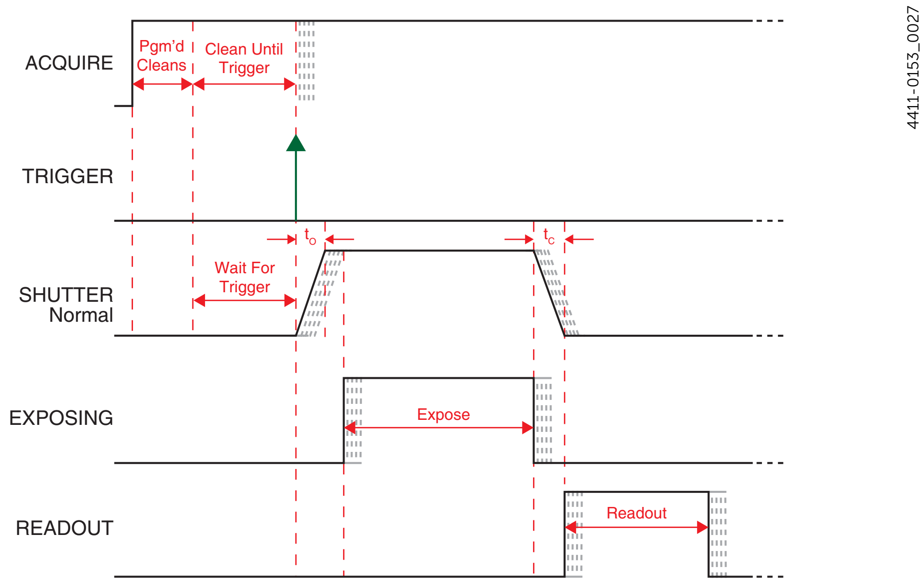


7.3.1.1 Normal Shutter Mode

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

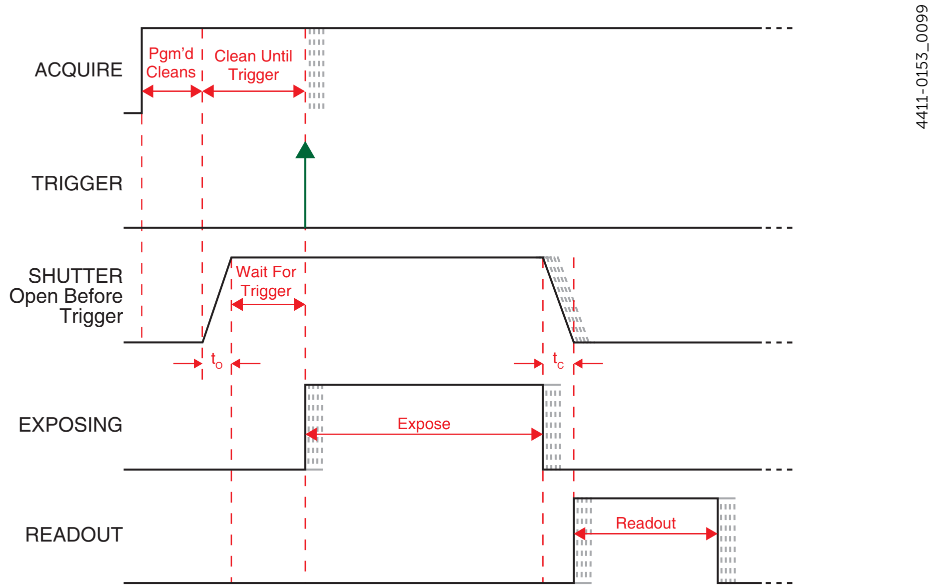


7.3.1.2 Open Before Trigger Mode

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



If the trigger arrives while a cleaning pattern is executing, the pattern will be completed, then cleaning will cease. This could result in vertical smear. The cleaning pattern is under user control in LightField, and the use of a cleaning pattern with only one vertical shift will reduce the vertical smear to at most one row.

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, may be dark current limited, and may also be more sensitive to cosmic rays. High-rho (ρ) CCDs are markedly more sensitive to cosmic rays.

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Chapter 8: Analog to Digital Conversion

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

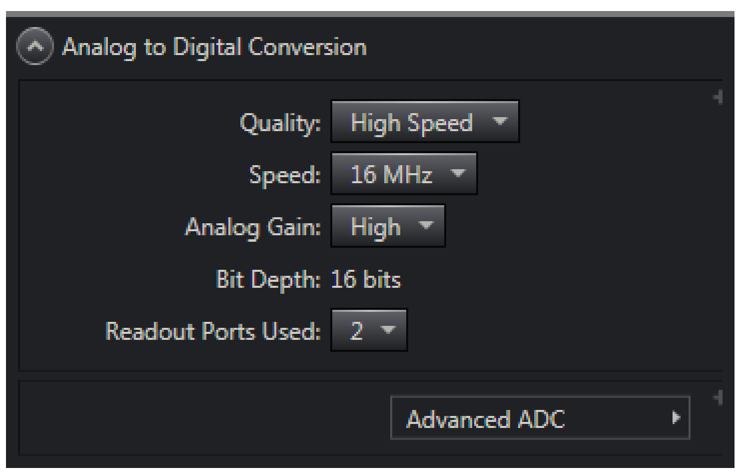
- Read out;
- Converted to a digital format;
- Transferred to the application software where it can be displayed and/or stored.

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. The following parameters are able to be configured:

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

See Figure 8-1.

Figure 8-1: Typical Analog to Digital Conversion Expander



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

8.1 Quality

BLAZE is equipped with two pairs of output amplifiers/ports:

- One pair of outputs incorporates two low noise amplifiers;
- One pair of outputs incorporates two high speed amplifiers.

The active pair of output ports is selected using the Quality parameter configuration within LightField.

NOTE:

Whether using Low Noise or High Speed amplifiers, one or two readout ports can be active. Refer to Section 8.2, Readout Ports Used, on page 62 for complete information.

Output amplifiers amplify the collected charge from the output node and transfer it to the ADC. Refer to Table 8-1 for typical examples of the relationship between the Quality configuration and Analog Gain configuration.

Table 8-1: Typical Relationship Between Quality and Analog Gain Configuration

Quality	Analog Gain		
	Low	Medium	High
Low Noise	5 e^-/count	1.7 e^-/count	0.7 e^-/count
High Speed	Not User Selectable		

8.2 Readout Ports Used

Readout begins by moving charge from the CCD image area to the shift register pixels which typically have twice the capacity of each image pixel.

All BLAZE systems feature dual amplifiers. Users can choose to use one or two outputs on any BLAZE. Using only one amplifier increases the readout time, but prevents mismatch artifacts which may arise in dual-port mode. The two ports are closely matched at the factory, but are not identical. Users can easily try each mode and decide which one better suits the specific requirements of the current experiment.

8.2.1 Low Noise Output Amplifiers

Figure 8-2 illustrates the charge being shifted and read out using two Low Noise Amplifier output ports.

Figure 8-2: Data Readout Using Two Low Noise Output Ports

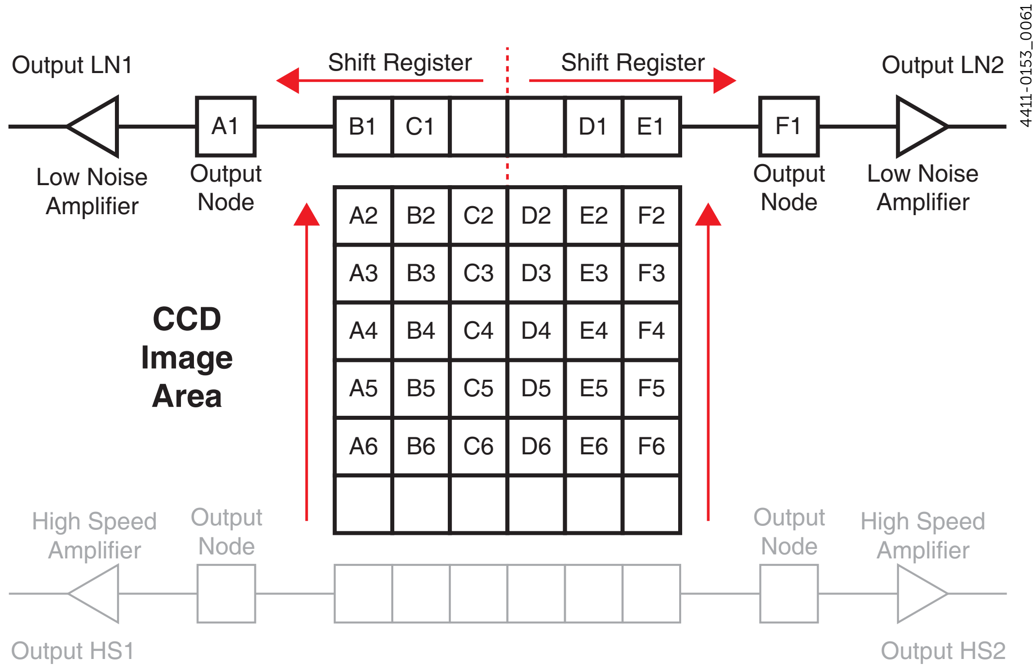
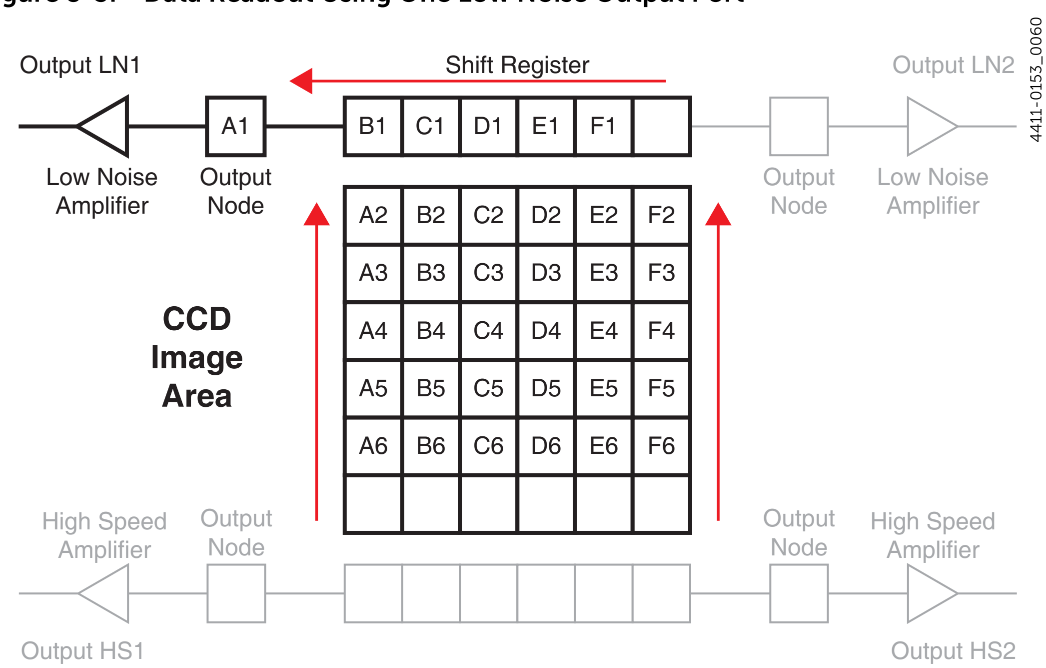


Figure 8-3 illustrates the same charge being shifted and read out using one BLAZE output port.

Figure 8-3: Data Readout Using One Low Noise 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 the electrons are grouped as electrons/count.

8.2.2 High Speed Output Amplifiers

Figure 8-4 illustrates the charge being shifted and read out using two High Speed output ports.

Figure 8-4: Data Readout Using Two High Speed Output Ports

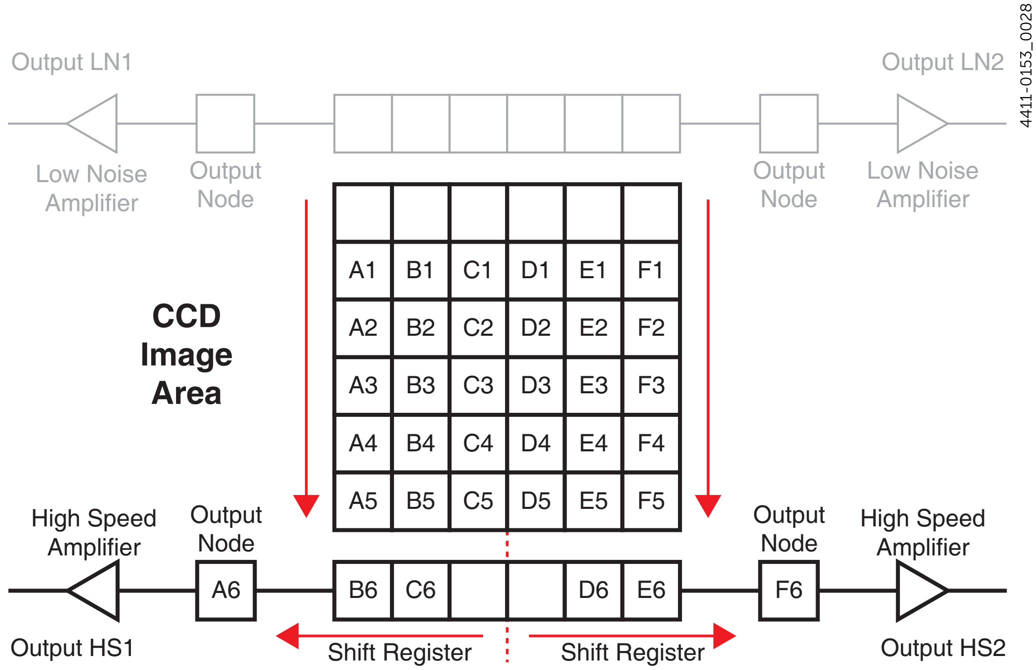
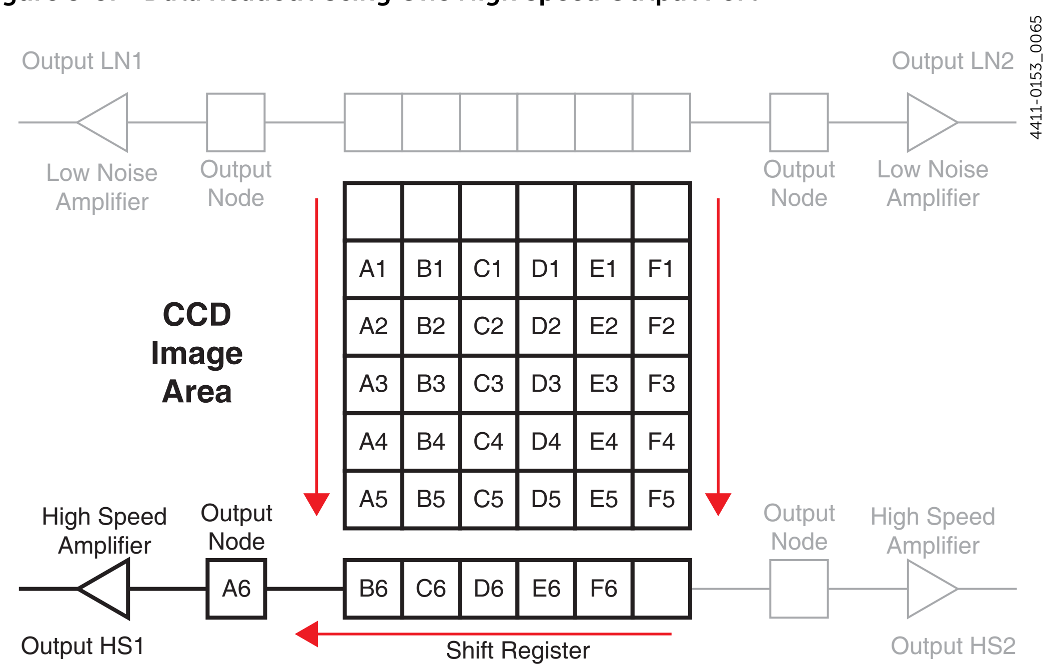


Figure 8-5 illustrates the same charge being shifted and read out using one High Speed output port.

Figure 8-5: Data Readout Using One High Speed Output Port



8.3 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, by design, set to 16.

Factors associated with digitization include:

- Speed

  This is software configurable within LightField, and specifies the rate at which data are digitized.
- **ADC Offset (Bias)**.

  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.

8.3.1 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.

BLAZE provides users flexibility regarding how quickly data are digitized based on the Quality that has been configured:

- High Speed Readout

  When High Speed readout has been selected, the following digitization speeds are supported:
  - 6.25 MHz;[1]
  - 10 MHz;
  - 16 MHz.
- Low Noise Readout

  When Low Noise readout has been selected, the following digitization speeds are supported:
  - 100 kHz;
  - 1 MHz;
  - 5 MHz[2].

NOTE:

For high-rho (ρ) CCDs:

- The slowest speed available on the High Speed Output is 5 MHz;
- The fastest speed available on the Low Noise Readout is 4 MHz.

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

1. For high-rho (ρ) CCDs, this is 5 MHz.
2. For high-rho (ρ) CCDs, this is 4 MHz.

8.3.2 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. A 500-600 ADU offset is included to avoid loss of signal when noise and/or drift might inadvertently result in a signal < 0 ADU. 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 170 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.

8.3.2.1 Correct Pixel Bias

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

Pixel bias correction operates by reading an artificially created row, which has essentially no charge, at the start of the frame and subtracting the row average from all following pixels in the frame. Therefore it adds one row readout time to the frame time. This is particularly useful when data are to be collected over a long time and maximum baseline stability is important.

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

8.4 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 BLAZE specifies the measured gain values for various Analog Gain settings.

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

Table 8-2: Typical Electron Counts vs. Analog Gain Setting

Low	Medium	High
5 e^-/count	1.7 e^-/count	0.7 e^-/count

8.4.1 Example

In this example, it is assumed the incoming light level is identical in all three instances. The electron counts listed in Table 8-2 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.

  For example, one could bin 10 pixels vertically, with 32500 electrons in each pixel, and still remain on scale. At Medium or High gain, the ADC would be over-ranged by approximately five (5) times.
- 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. For example, using the light level as in the above example, only three (3) pixels binned vertically can be handled.
- 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.

Chapter 9: Full Frame Readout

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

REFERENCES:

Refer to Section 8.2, Readout Ports Used, on page 62 for complete information about selecting the number of ports used.

NOTE:

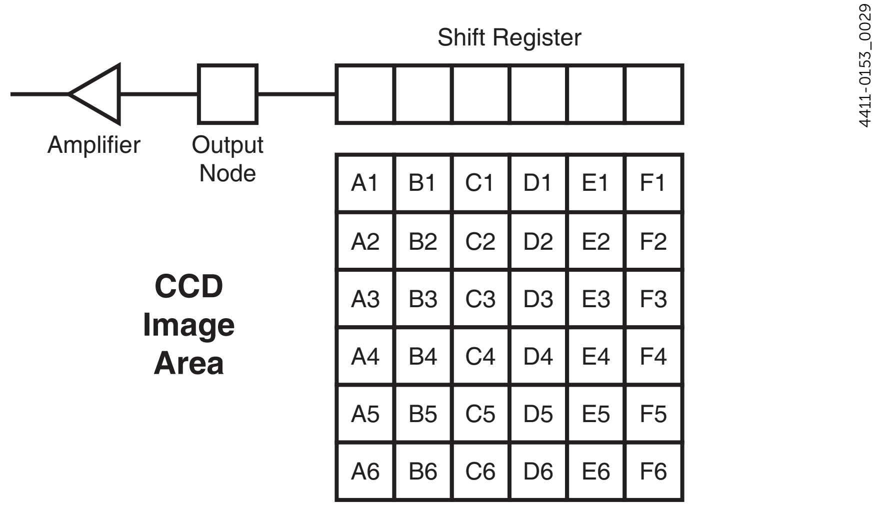
For simplicity, this chapter describes a BLAZE system that has been configured to read out data using a single output port. Similar processes are employed when using 2 ports.

Figure 9-1 illustrates a CCD array following exposure but prior to the beginning of readout.

NOTE:

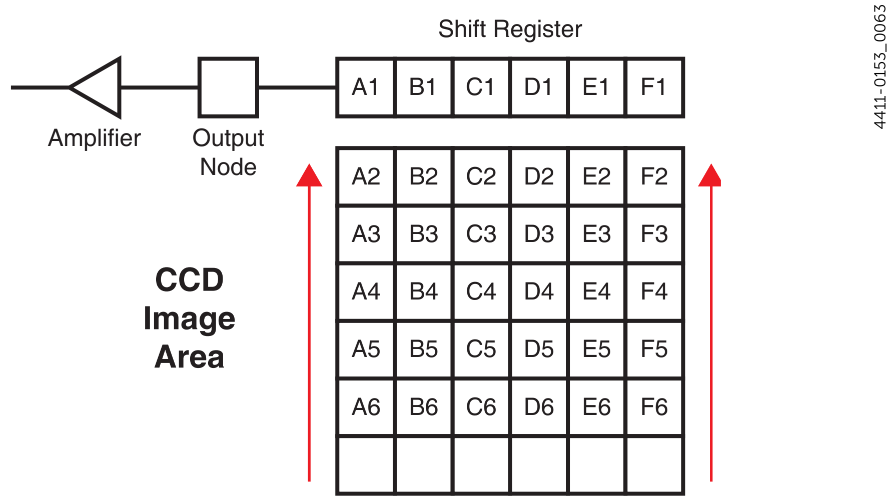
Capital letters represent different amounts of accumulated charge, both desired signal and dark charge.

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

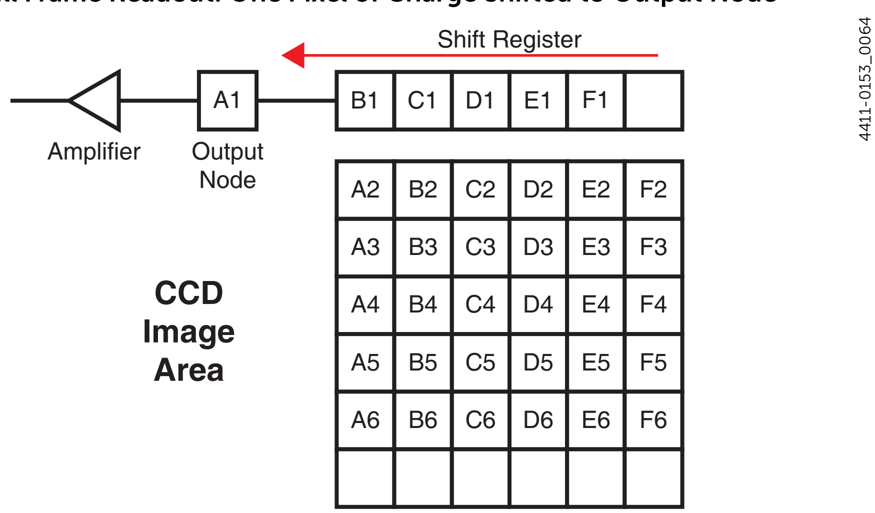


NOTE:

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



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) $$t_{FF} = t_R + t_{exp} + t_c$$

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 Table A-7, BLAZE External Shutter Specifications, on page 149 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 BLAZE is configured for 2-port readout, LightField accounts for very specific symmetry rules regarding ROI dimensions and placement.

CCD readout time is approximately calculated as follows:

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

where:

- t_R is the readout time;
- N_y is the number of rows within the CCD;
- N_x is the number of columns within the CCD;

  When BLAZE is configured for 2-port readout:

  N_x = ½ [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.

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 dimension 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

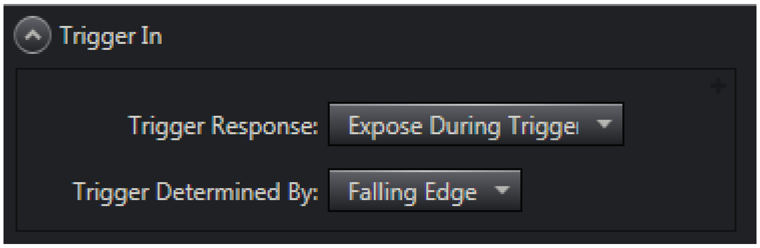
For many experiments, the acquisition of quality/useful data is dependent on precise synchronization with external experiment events. Using the EXT SYNC input on the rear of BLAZE, externally-generated trigger pulses can be used to control:

- Shutter operation;
- Data readout.

This section describes how to configure BLAZE 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



4411-0153_0030

Depending on the specific experiment, two parameters are used to configure BLAZE'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, BLAZE 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.

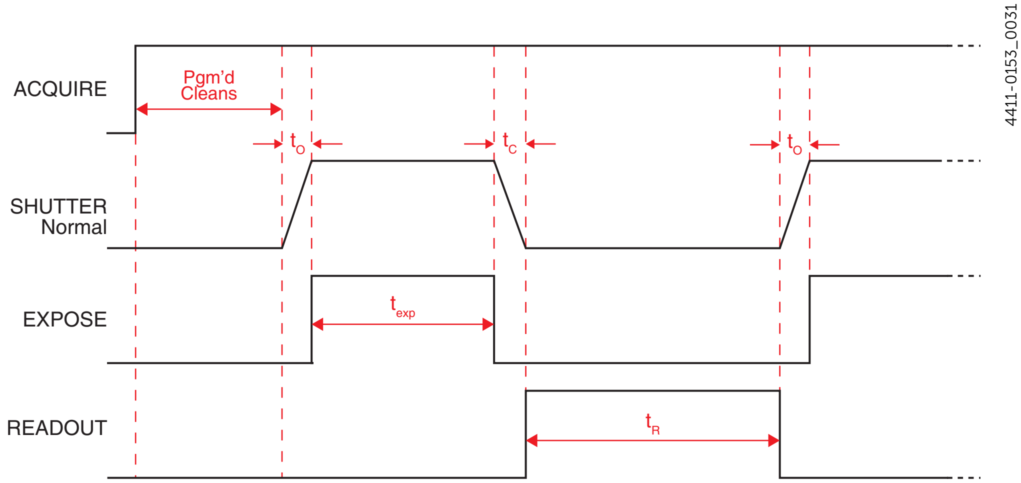
NOTE:

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.

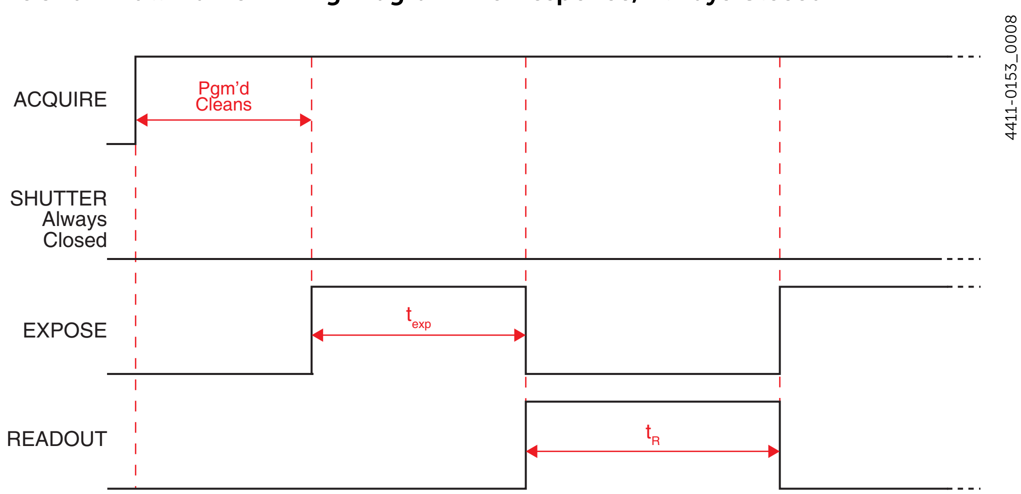
Figure 9-5: Full Frame Timing Diagram: No Response, Normal



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

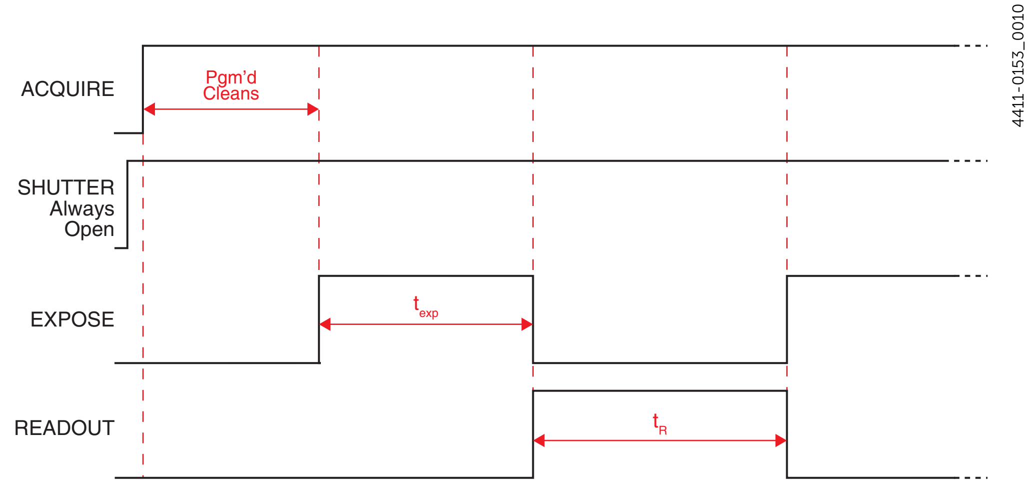


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

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 57 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

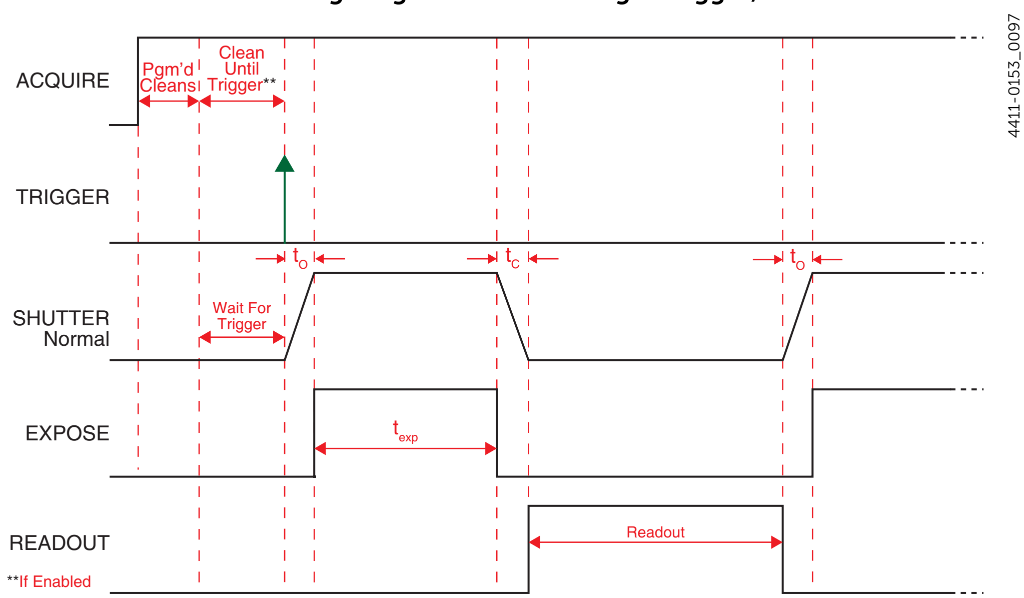
9.2.1.2.1 Normal

Figure 9-8 illustrates the timing diagram for Start on Single Trigger mode combined with Normal shutter mode.

NOTE:

In Figure 9-8, jitter associated with the cleaning pattern is omitted for clarity. See Figure 7-3 for jitter information.

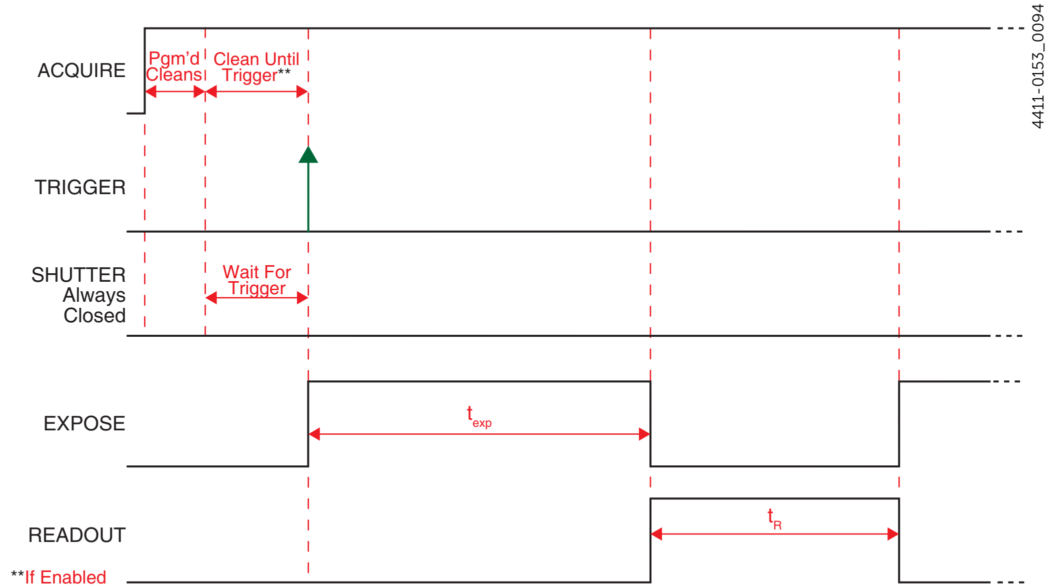
Figure 9-8: Full Frame Timing Diagram: Start on Single Trigger, Normal



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

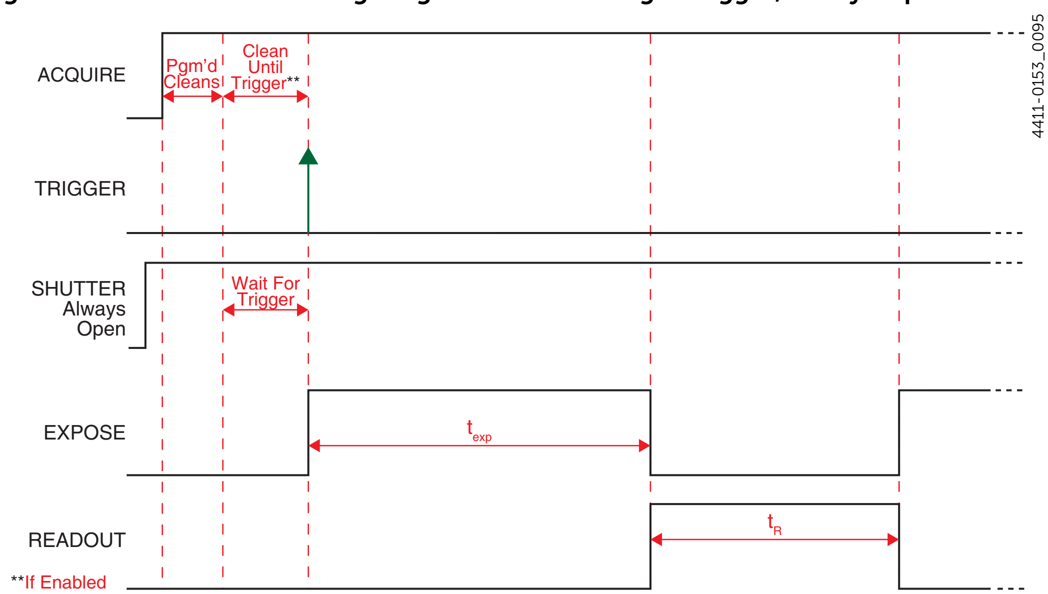


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

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.)

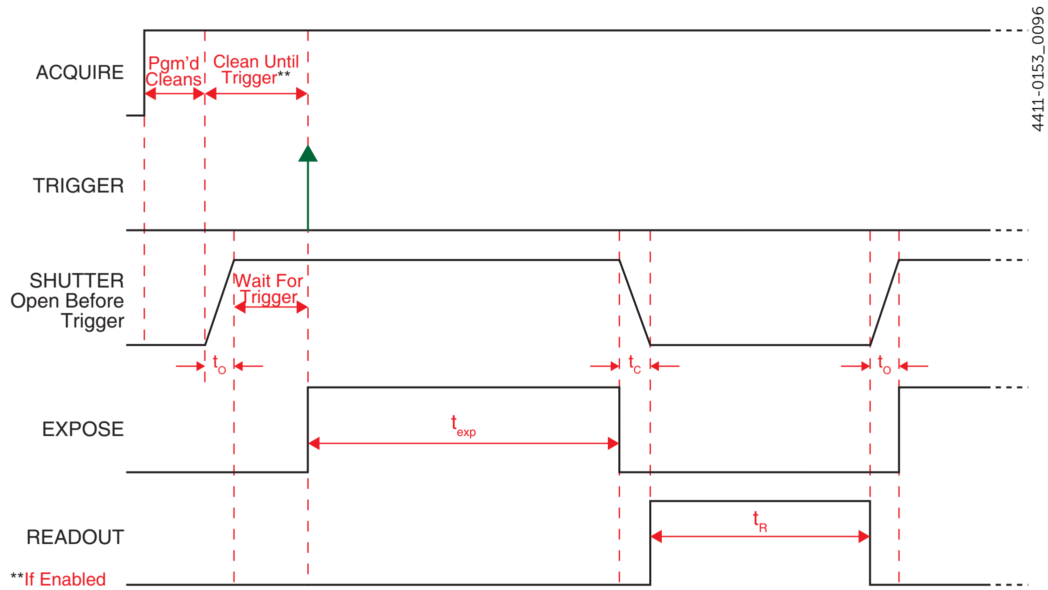
9.2.1.2.4 Open Before Trigger

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

NOTE:

In Figure 9-11, jitter associated with the cleaning pattern is omitted for clarity. See Figure 7-4 for jitter information.

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 85 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.

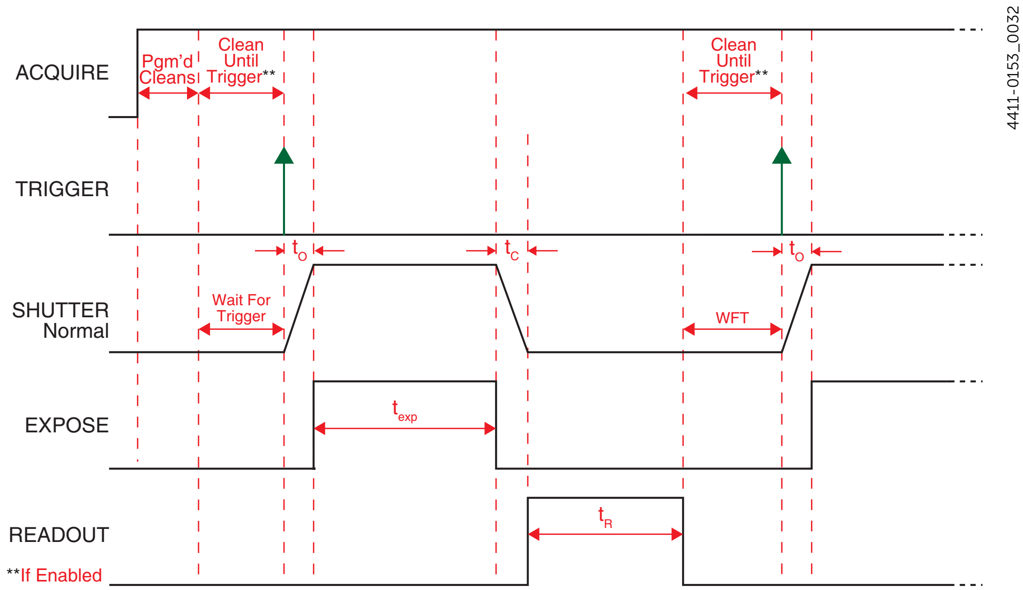
NOTES:

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 57 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, BLAZE 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.

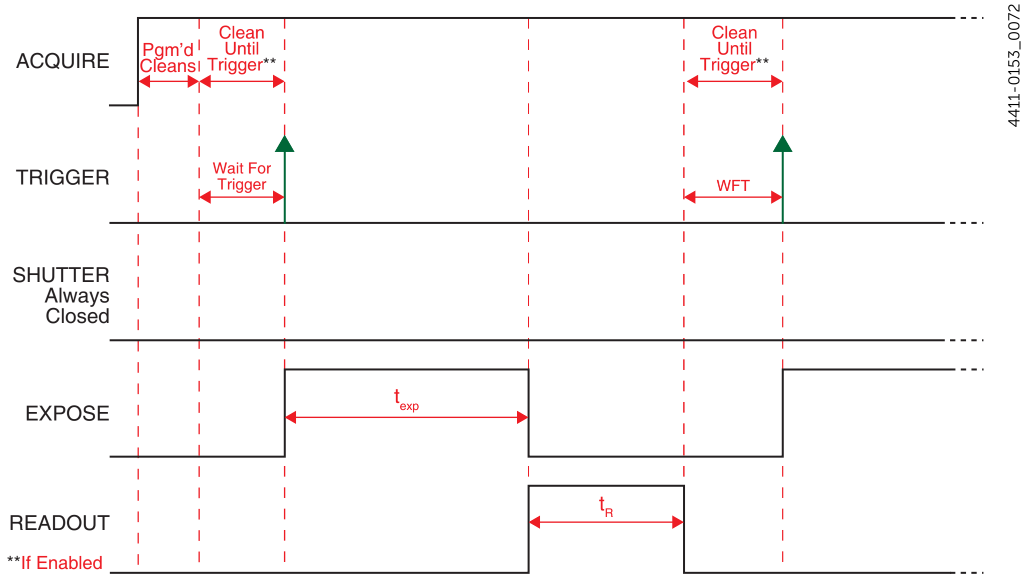
Because a shutter requires a finite length of time to fully open, the trigger pulse from the experiment must precede the start of data acquisition by at least this length of time. If it does not, the shutter may not be completely open throughout the duration of the desired data acquisition, and data acquisition may even be missed completely.

Since the amount of time from initialization of the experiment to the first trigger pulse is not fixed, an accurate background subtraction may not be possible for the first readout, nor for all subsequent shots since the trigger is external, is not synchronous with the camera, and therefore not synchronous with the cleaning cycle.

9.2.1.3.2 Always Closed

Figure 9-13 illustrates the timing diagram for Readout Per Trigger mode combined with Always Closed shutter mode.

Figure 9-13: Full Frame Timing Diagram: Readout Per Trigger, Always Closed

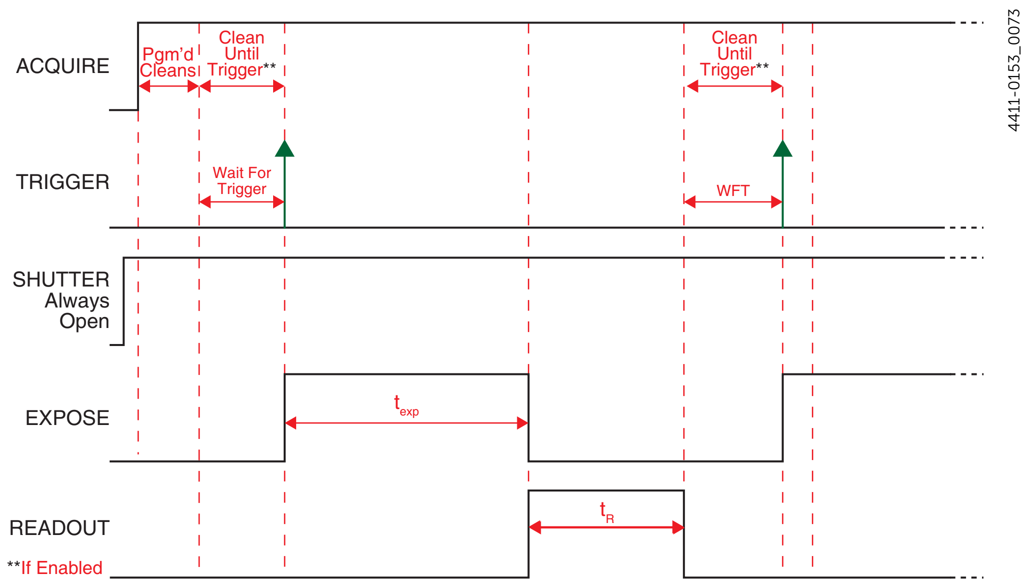


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that the dark reference file is typically unnecessary.

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

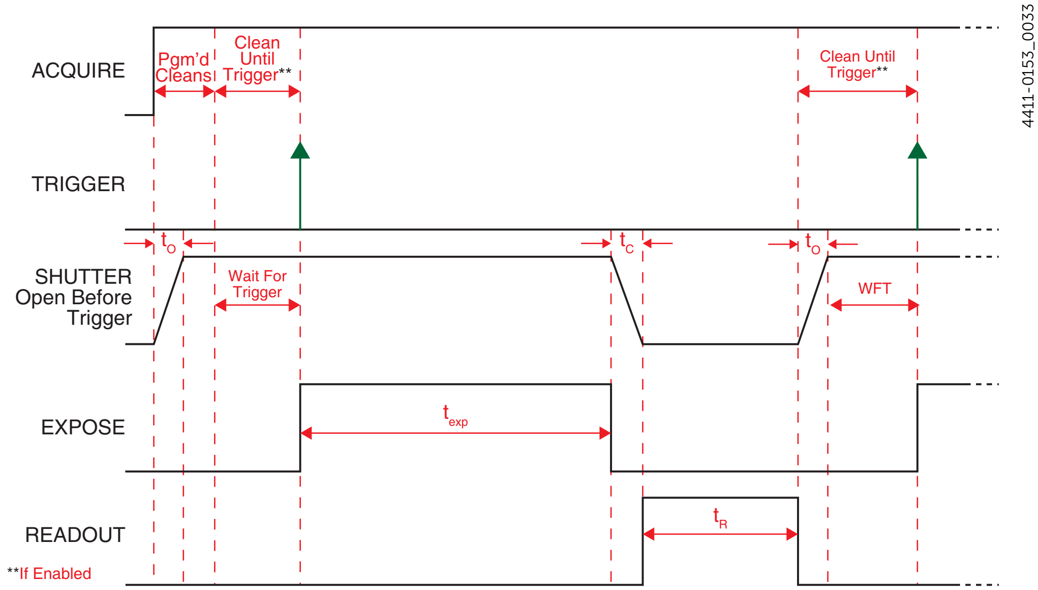


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) Open Before Trigger is closely related.

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 57.) 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.

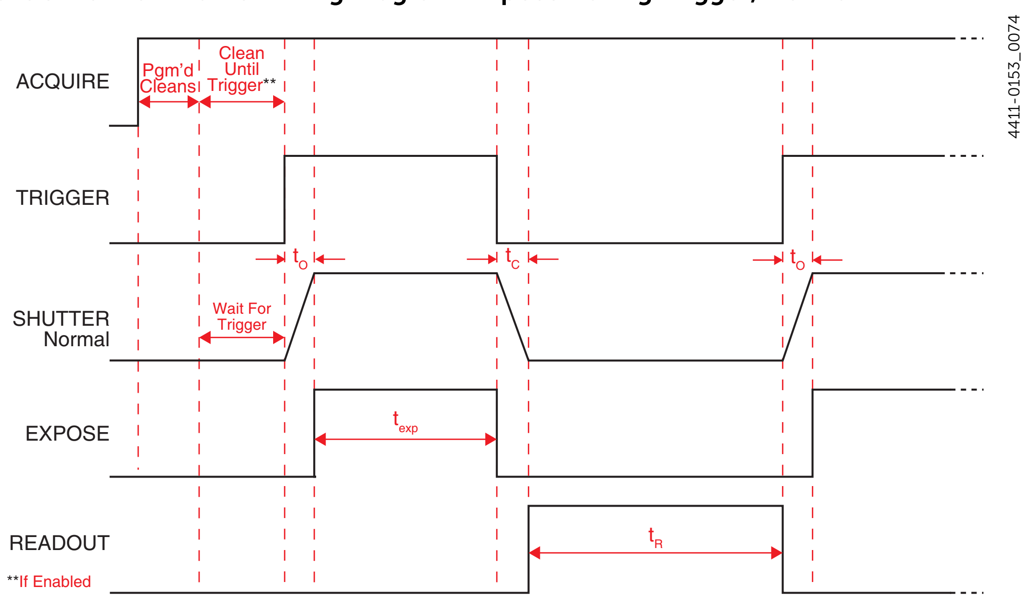
NOTES:

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 57 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.

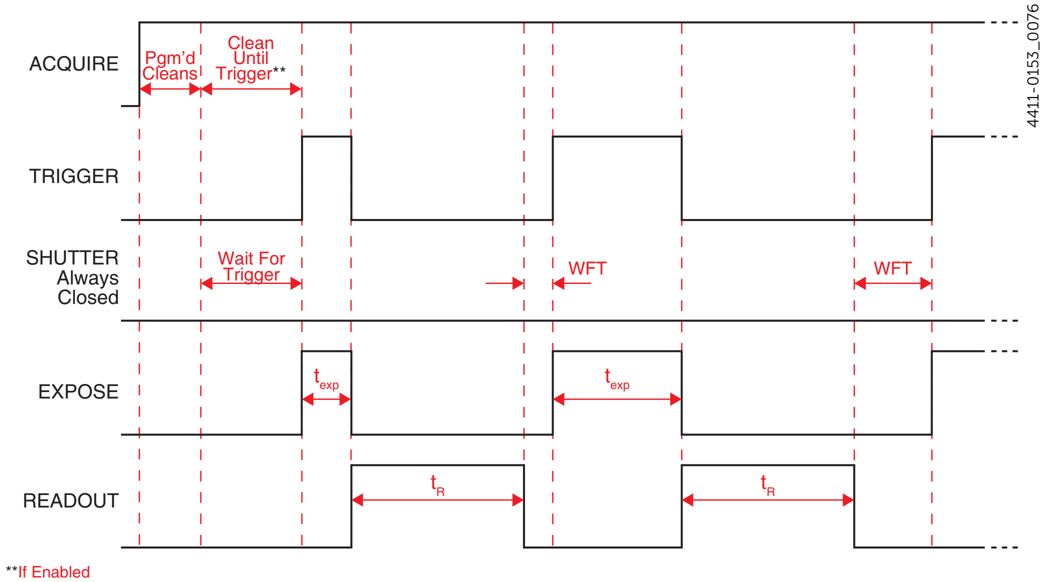
Figure 9-16: Full Frame Timing Diagram: Expose During Trigger, Normal



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

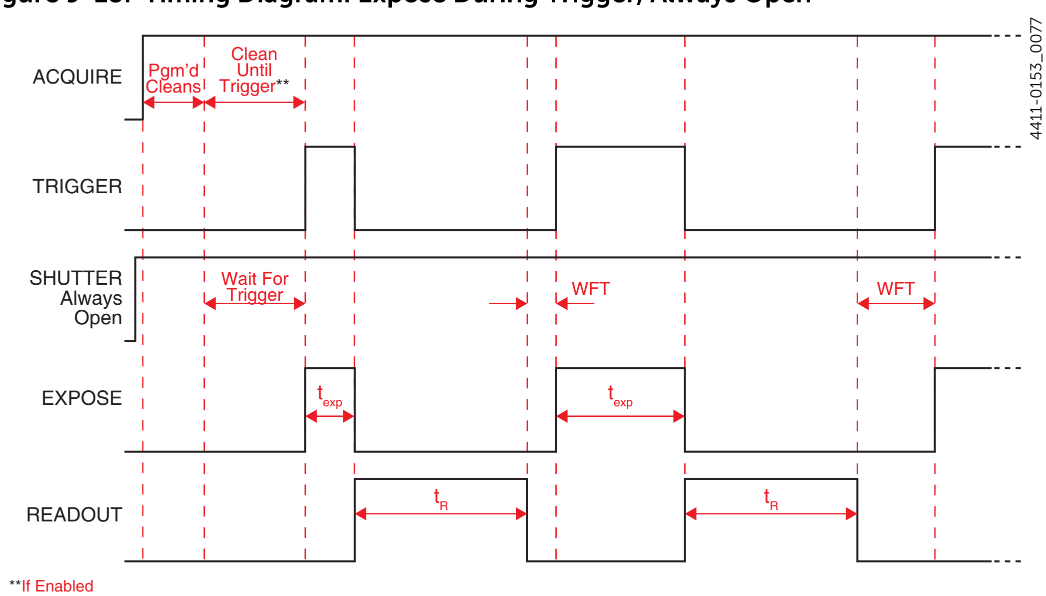


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that the dark reference file is typically unnecessary.

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

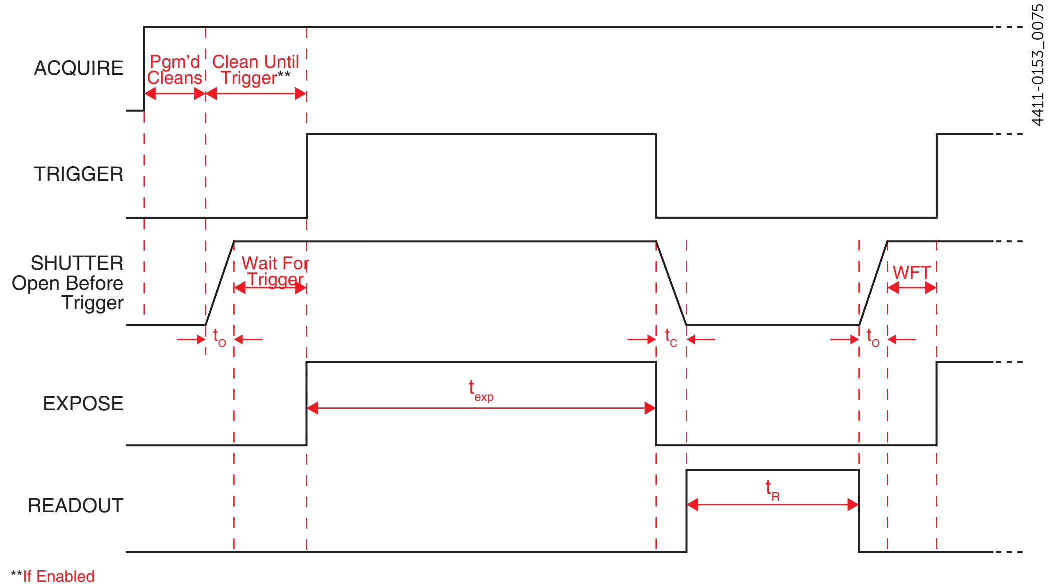


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) Open Before Trigger is closely related.

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, BLAZE 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;

  BLAZE 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 73 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 82 illustrate this.

  NOTE:

  If BLAZE is busy when a subsequent trigger pulse is received, the trigger is ignored.

- Falling Edge

  BLAZE 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 73 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:

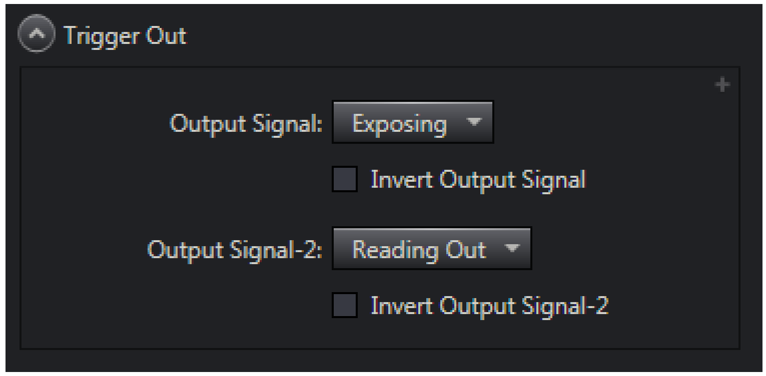
  If BLAZE is busy when a subsequent trigger pulse is received, the trigger is ignored.

9.3 Trigger Out

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

Two trigger out pulses are configured on the Trigger Out expander, shown in Figure 9-20.

Figure 9-20: Typical Trigger Out Expander



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

- Acquiring;
  The associated output signal is high when BLAZE 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 BLAZE cameras.
  When using Kinetics Readout (refer to Chapter 10, Kinetics Readout, on page 87,) 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 BLAZE 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.

Chapter 10: Kinetics Readout

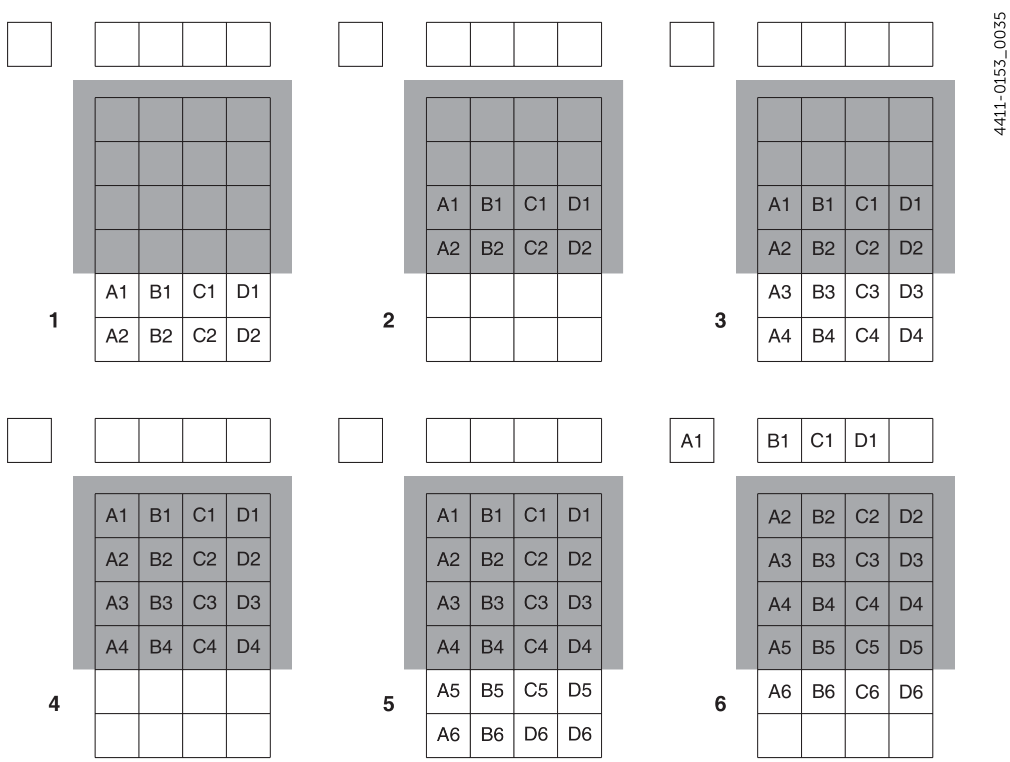
Kinetics mode uses the CCD to expose and store a limited number of images in rapid succession. The time it takes to shift each line (or row) on the CCD is as short as a few hundred nanoseconds to few microseconds, depending on the CCD. Therefore the time between images can be as short as a few microseconds. Kinetics mode allows full frame CCDs to take time-resolved images/spectra. Optical or mechanical masking of the array is required.

NOTE:

Because BLAZE supports 1- or 2-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.

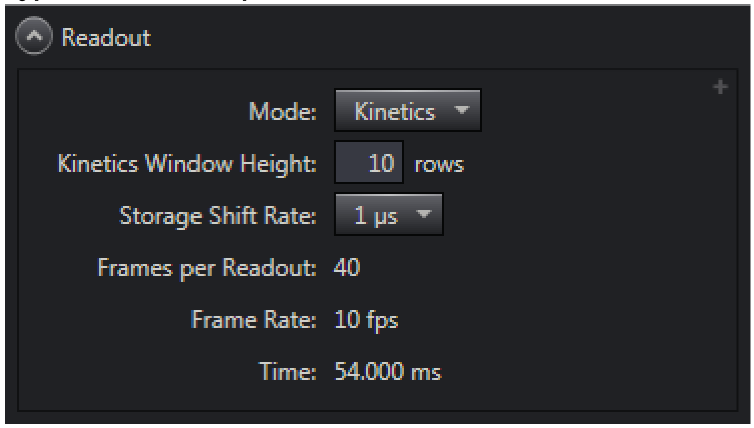
Figure 10-1: 1-Port Kinetics Readout



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



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 depend on the BLAZE model being used:

- BLAZE: 100 models:
  [1 ... 50] rows, inclusive, in 1 row increments.
- BLAZE: 400 models:
  [1 ... 200] 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:

- 4 μs;
- 8 μs;
- 10 μs;
- 20 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 BLAZE, externally-generated trigger pulses can be used to control:

- Shutter Operation;

REFERENCES:

Refer to Chapter 13, Shutter Control, on page 139 for detailed information about each available shutter mode.

CAUTION!

Although NORMAL Shutter mode is available in Kinetics Readout, programming a BLAZE 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.

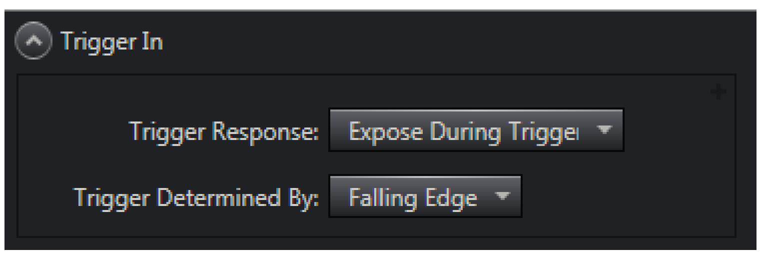
If an application requires both NORMAL shutter mode and Kinetics Readout, contact Teledyne Princeton Instruments for assistance prior to attempting this configuration. Refer to Contact Information on page 170 for complete information.

- Data Readout.

This section describes how to configure BLAZE 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



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Depending on the specific experiment, two parameters are used to configure BLAZE'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 BLAZE 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, BLAZE 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 4 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 µs/row, the Shift time is 48 µs per frame. If the shift rate is increased to 80 µs/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

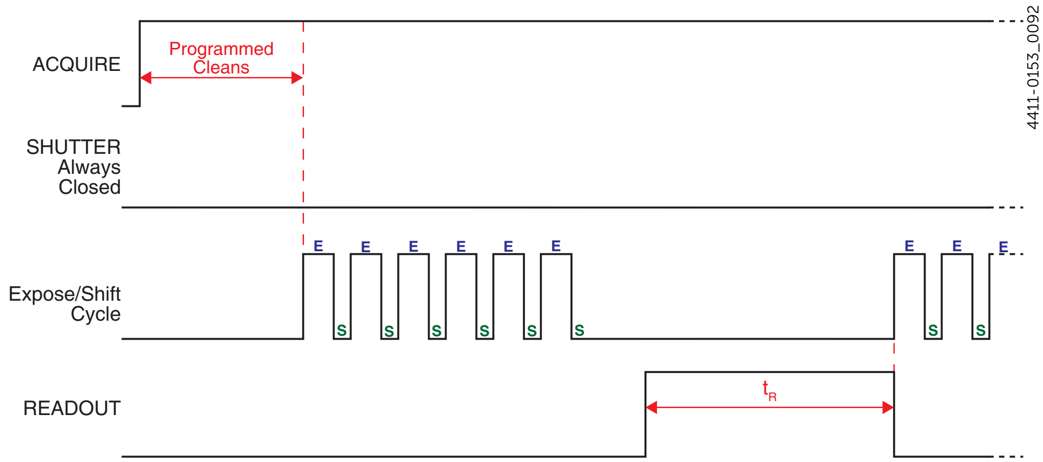
CAUTION!

The use of this mode is strongly discouraged. Contact Teledyne Princeton Instruments for assistance before implementing this mode. Refer to Contact Information on page 170 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

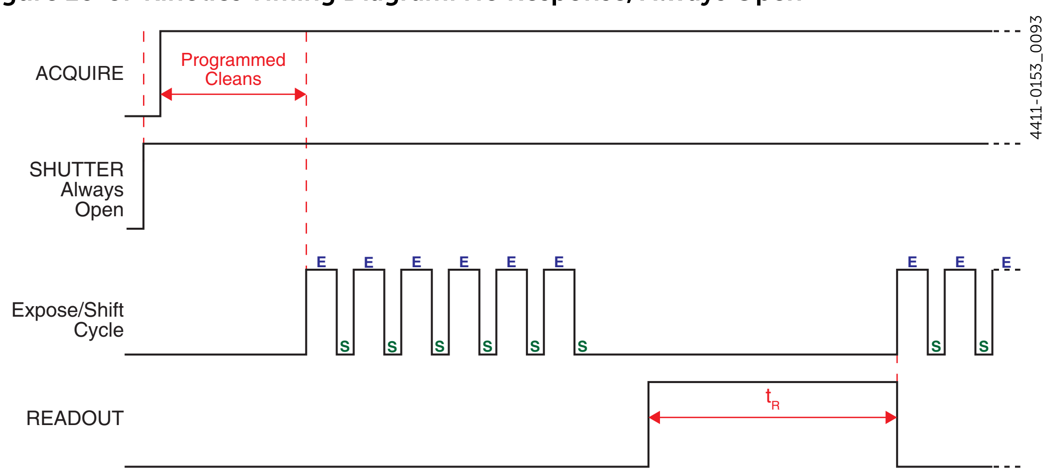


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

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 57 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.2.1 Normal

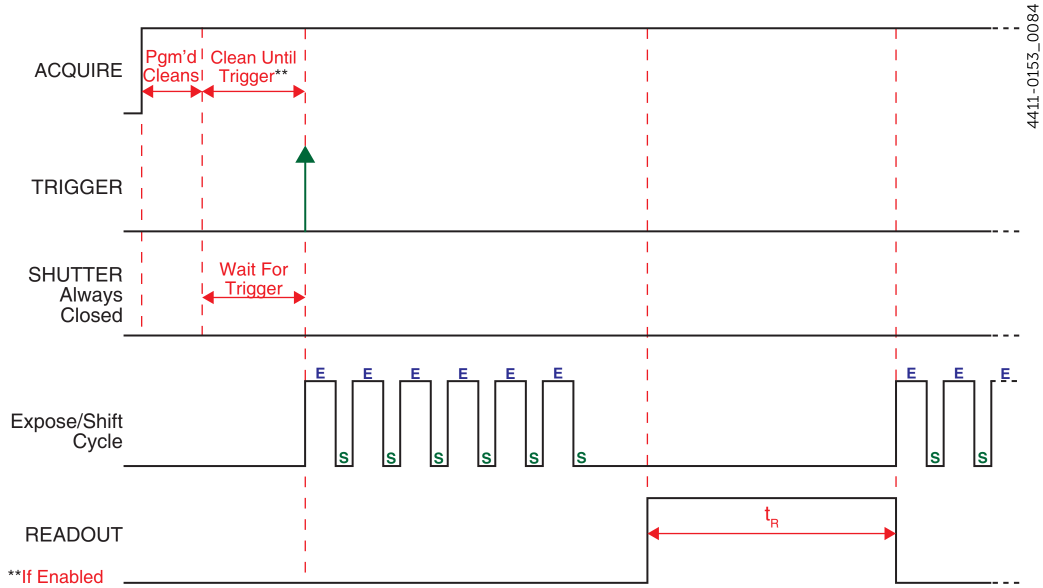
CAUTION!

The use of this mode is strongly discouraged. Contact Teledyne Princeton Instruments for assistance before implementing this mode. Refer to Contact Information on page 170 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

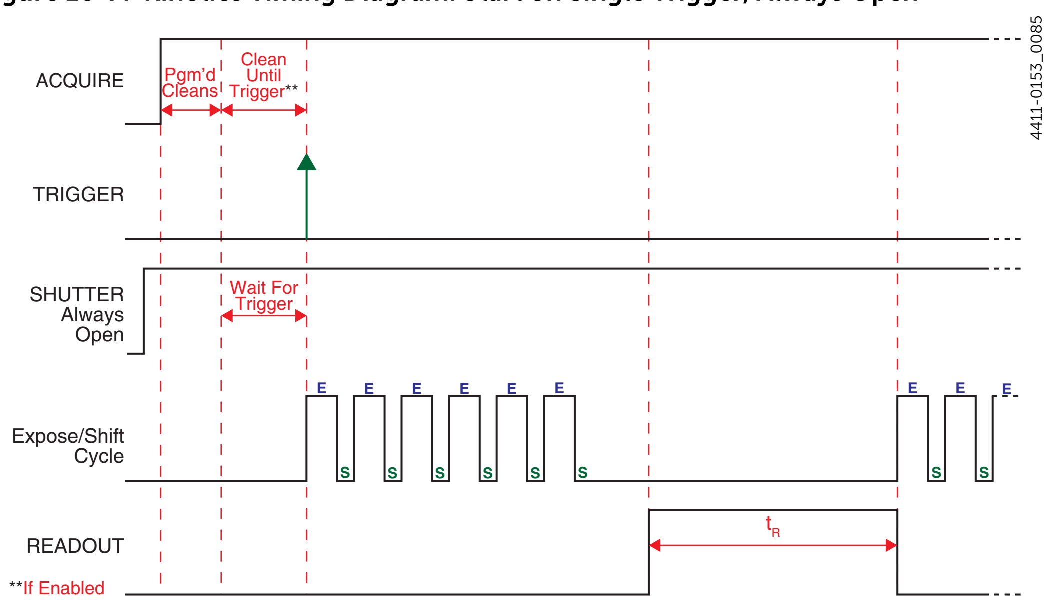


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

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

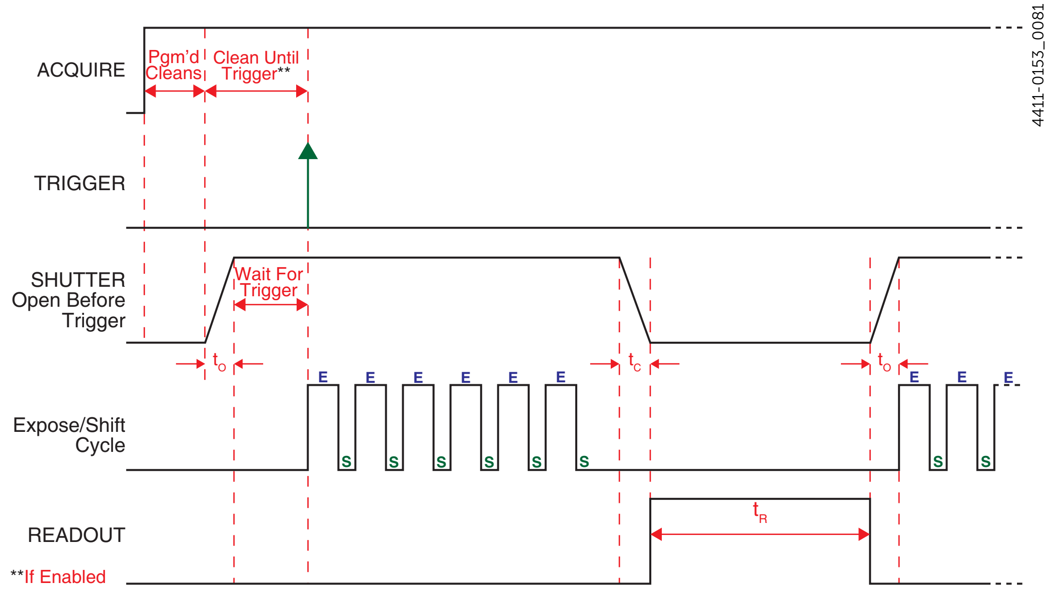


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.)

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



10.2.1.3 Readout Per Trigger

When configured for Readout Per Trigger, BLAZE 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;
- BLAZE acquires data using the configured Exposure Time;
- An external trigger is applied to the SYNC connector on the rear of BLAZE.

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, BLAZE 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 57 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.3.1 Normal

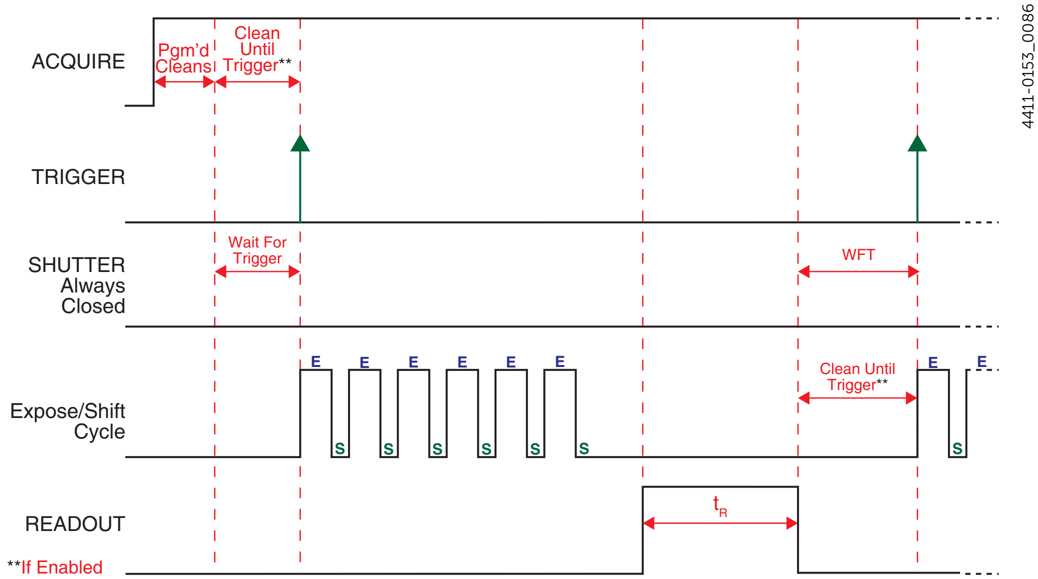
CAUTION!

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 170 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

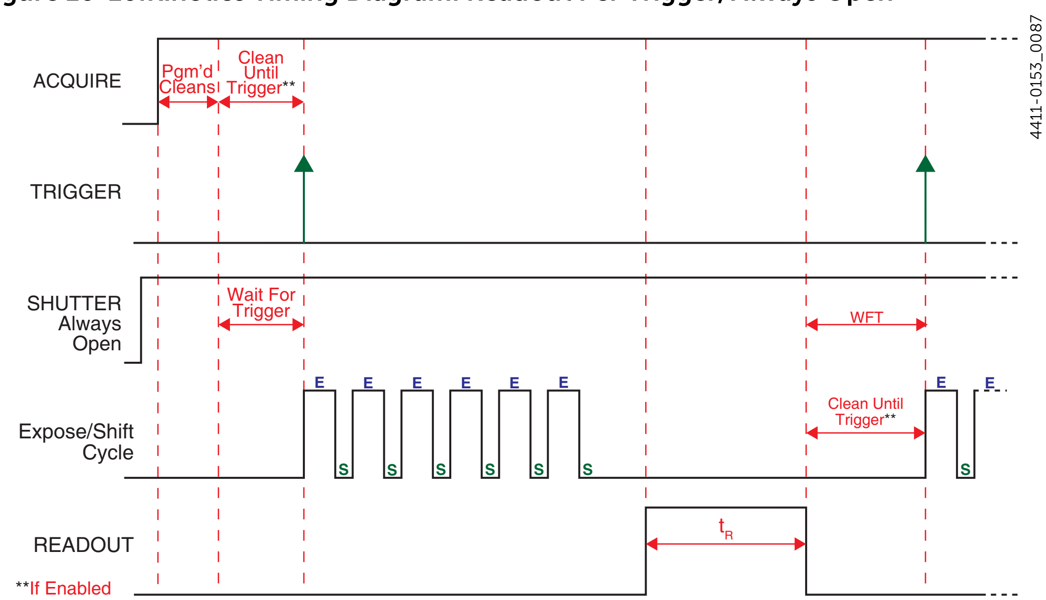


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

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

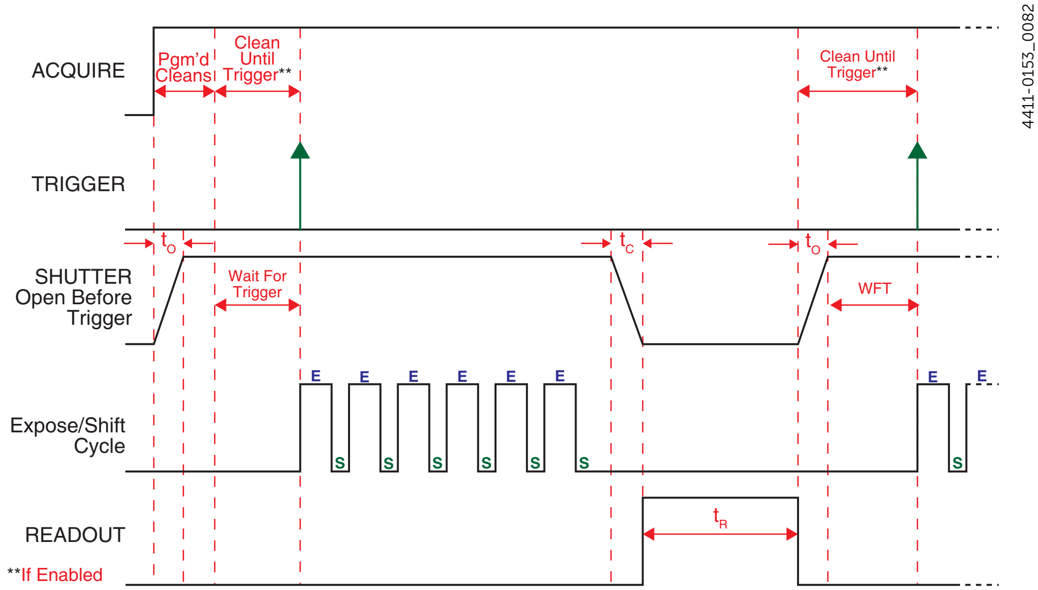


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) Open Before Trigger is closely related.

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, BLAZE'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 57 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.4.1 Normal

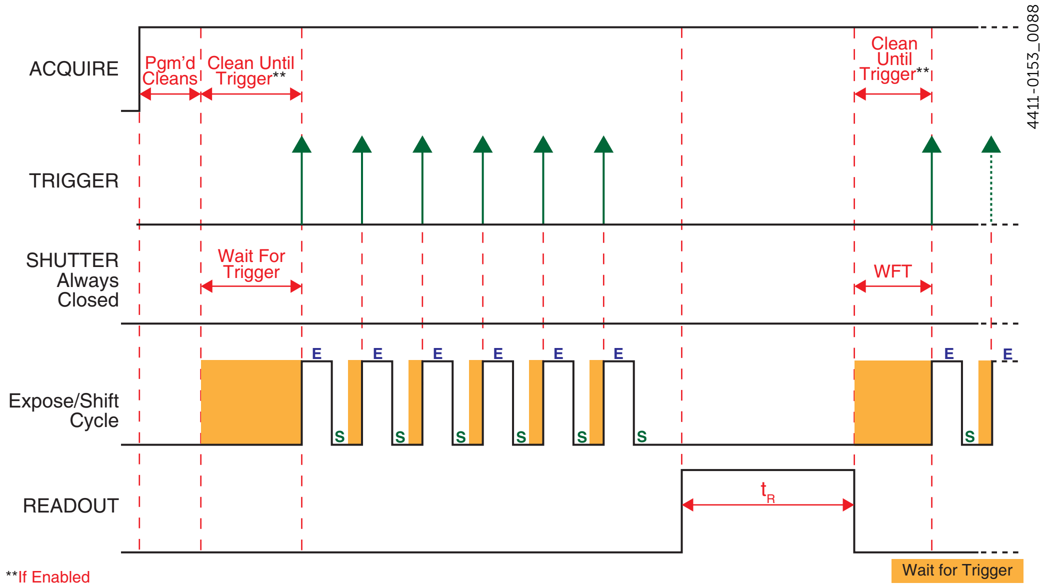
CAUTION!

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 170 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

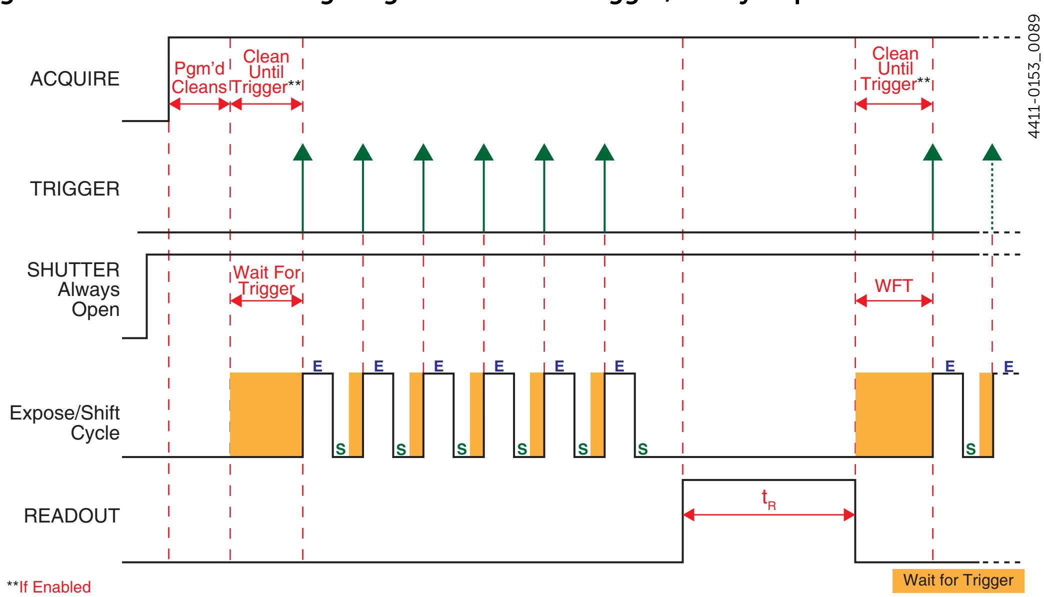


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

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

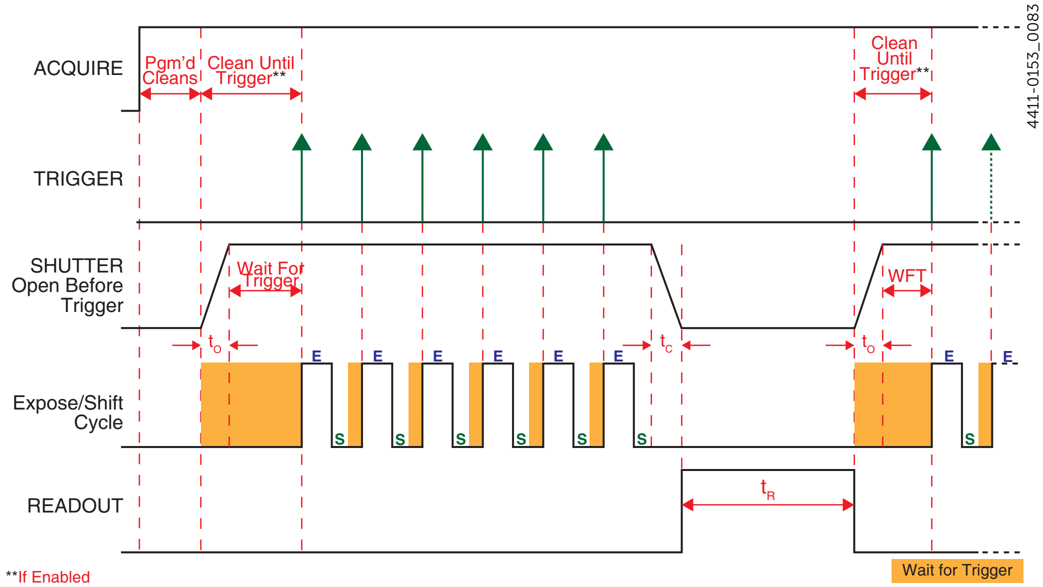


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) Open Before Trigger is closely related.

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 57 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

10.2.1.5.1 Normal

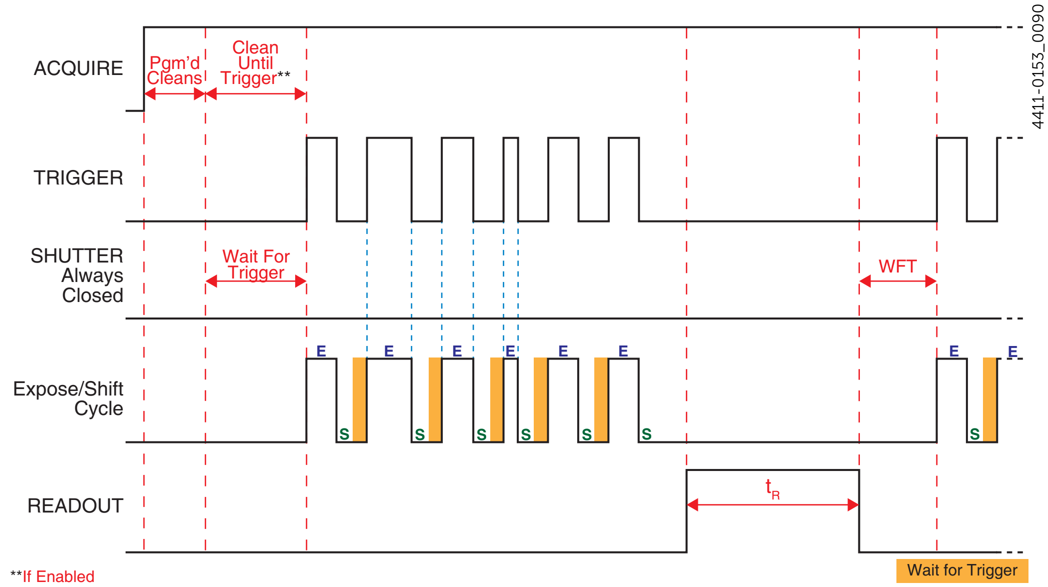
CAUTION!

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 170 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

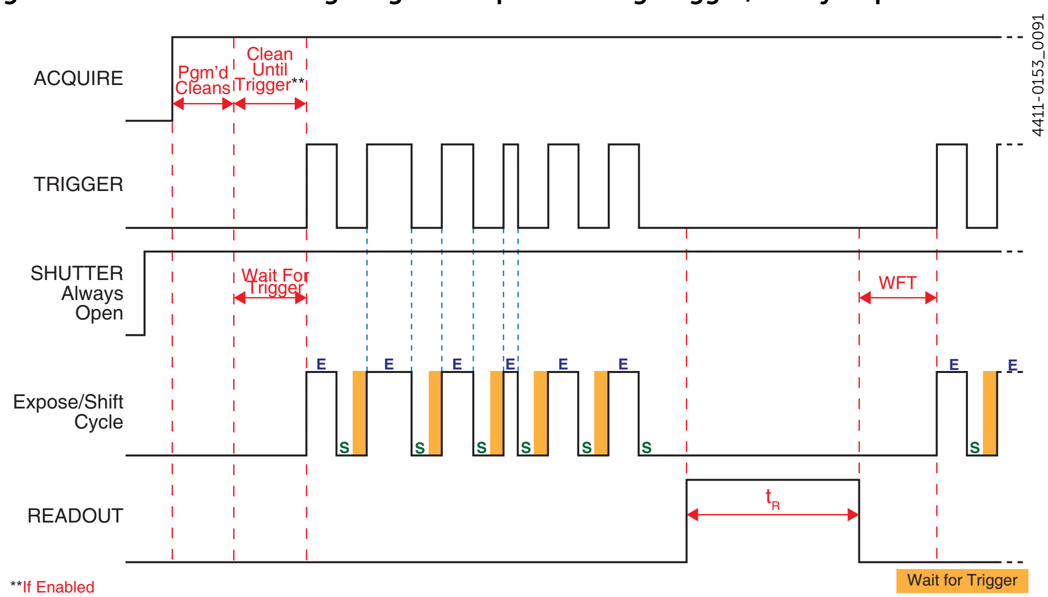


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

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

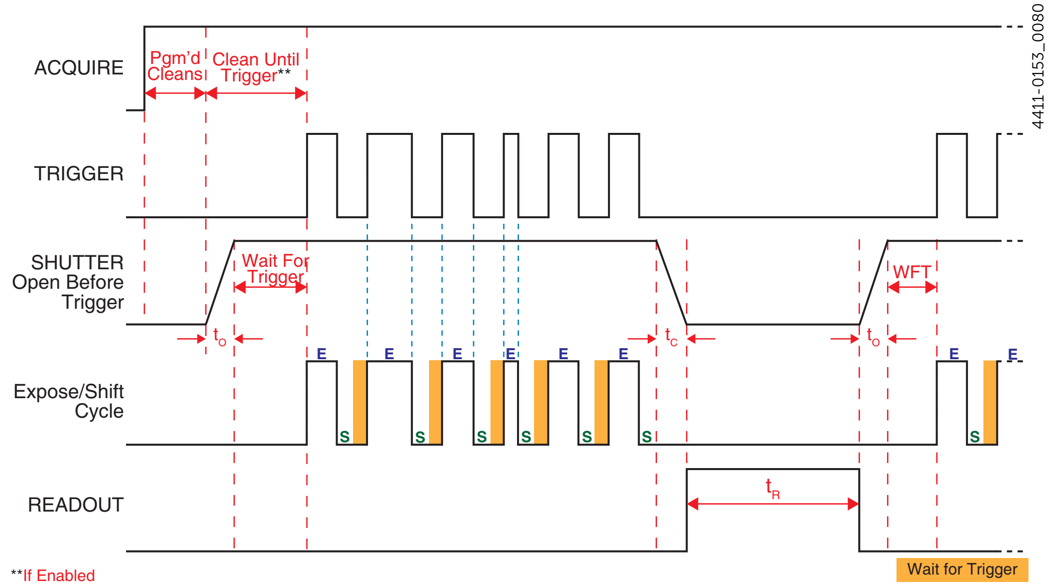


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) Open Before Trigger is closely related.

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, BLAZE 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;

  BLAZE 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 90 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 101 illustrate this.

  NOTE:

  If BLAZE is busy when a subsequent trigger pulse is received, the trigger is ignored.

- Falling Edge.

  BLAZE 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 90 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:

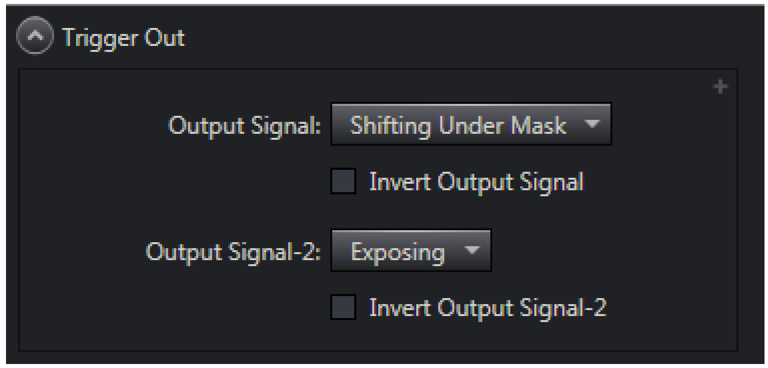
  If BLAZE is busy when a subsequent trigger pulse is received, the trigger is ignored.

10.3 Trigger Out

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

Two trigger out pulses are configured on the Trigger Out expander, shown in Figure 10-18.

Figure 10-18:Typical Trigger Out Expander



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

- Acquiring;
  The associated output signal is high when BLAZE 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 BLAZE 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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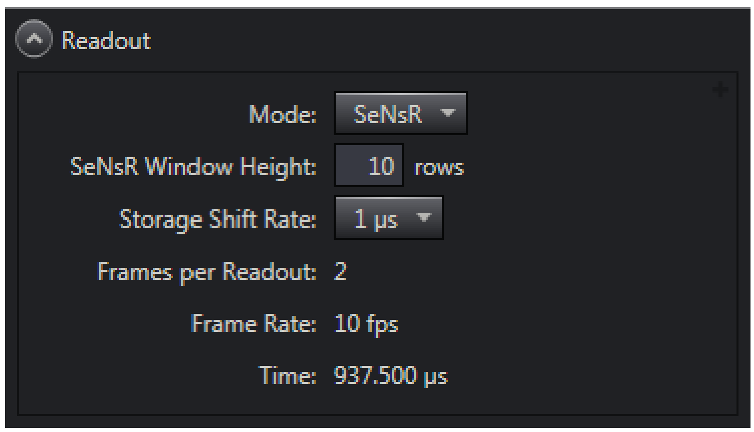
Chapter 11: SeNsR Readout

As discussed previously in Section 2.1.2, SeNsR, on page 19, SeNsR incorporates a CCD in which the image area may be divided into three horizontal strips in which each strip is comprised of the same number of rows. The top and bottom strips are used for temporary charge storage while the center strip is exposed to the spectrum of interest. Software configures the imaging so that the center imaging strip is as centered as the CCD dimensions allow.

11.1 SeNsR Mode Parameters

SeNsR mode is selected and configured on the Readout expander as shown in Figure 11-1.

Figure 11-1: Typical Readout Expander: SeNsR Mode Parameters



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Once SeNsR Mode is selected, parameters are enabled on the following expanders:

- Readout Expander;
- Common Acquisition Settings Expander;
- Trigger In;
- Trigger Out.

11.1.1 Readout Expander

This section provides information about SeNsR parameters accessed on the Readout expander.

11.1.1.1 SeNsR Window Height

Defines the height, in rows, of the unmasked area of the CCD to be used for SeNsR.

Valid values depend on the BLAZE model being used:

- BLAZE: 100 models:
  [1 ... 33] rows, inclusive, in 1 row increments.
- BLAZE: 400 models:
  [1 ... 133] rows, inclusive, in 1 row increments.

11.1.1.2 Storage Shift Rate

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

Valid values are:

- 750 ns;
- 1 μs;
- 2 μs;
- 3 μs.

NOTE:

Actual shift rates may vary based on the specific CCD that has been installed in the camera

11.1.1.3 Frames per Readout

In SeNsR Readout, this parameter is always set to 2.

11.1.1.4 Frame Rate

This calculated value indicates the rate of SeNsR Expose-Shift cycles (i.e., up and down shifts, plus exposure time.)

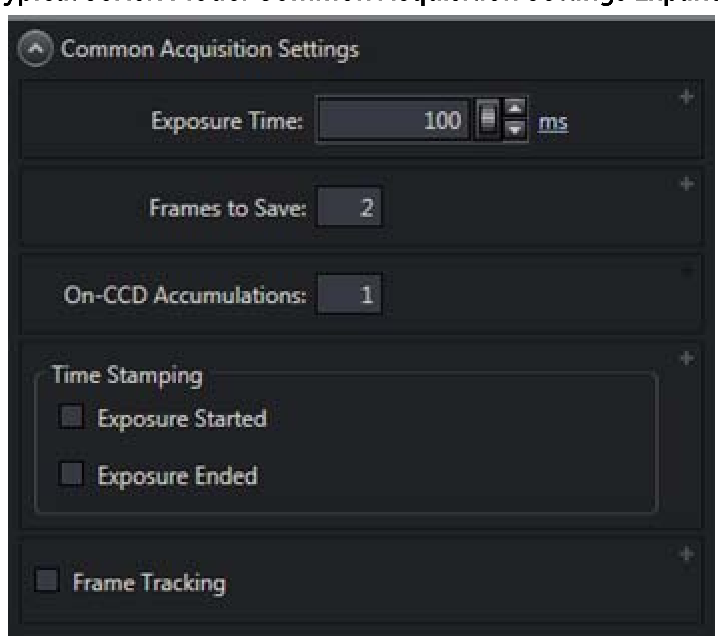
11.1.1.5 Time

This calculated value is the time required to read data from the sensor one time.

11.1.2 Common Acquisition Settings Expander

This section provides information about SeNsR parameters accessed on the Common Acquisition Settings expander. See Figure 11-2.

Figure 11-2: Typical SeNsR Mode: Common Acquisition Settings Expander



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11.1.2.1 On-CCD Accumulations

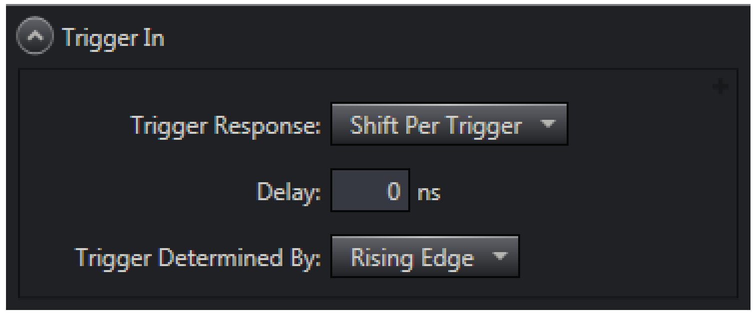
This parameter defines the number of frames that are accumulated on the sensor.

Valid values are [1 ... 65,535] frames, inclusive, in increments of 1 frame.

11.1.3 Trigger In

This section provides information about SeNsR parameters accessed on the Trigger In expander. See Figure 11-3.

Figure 11-3: Typical SeNsR Mode: Trigger In Expander



11.1.3.1 Trigger Response

This option defines how BLAZE responds to an incoming external trigger.

Valid values are:

- No Response;
  When selected, BLAZE does not respond to an incoming external trigger.
- Start On Single Trigger;
  When selected, following the receipt of an incoming trigger, BLAZE executes the programmed Expose/Shift sequence and reads out the frame of acquired data. See Figure 2-4, on page 19. BLAZE repeats this process in immediate succession for each programmed frame of data that is to be acquired until all data have been acquired.
- Readout Per Trigger;
  When selected, following the receipt of an incoming trigger, BLAZE executes the programmed Expose/Shift sequence and reads out the frame of acquired data. See Figure 2-4, on page 19. It then waits for a subsequent incoming trigger to begin the Expose/Shift sequence and data readout for the next frame of data. Data acquisition continues in this manner until all programmed frames of data have been acquired.
- Shift Per Trigger.
  When selected, following the receipt of an incoming trigger, BLAZE begins the programmed Expose/Shift sequence by exposing the imaging area to Spectrum 1. Additional incoming triggers are then required for each subsequent shift of data between the active imaging area and the two temporary storage areas. See Figure 2-4, on page 19. Once the complete programmed Expose/Shift sequence has been completed, one final incoming trigger is required to initiate the reading out of the acquired data.

11.1.3.2 Delay

This value specifies the delay, in nanoseconds (ns), between the receipt of an external trigger and when BLAZE responds.

Valid values are [0 … 4] seconds, in 10 ns increments.

11.1.3.3 Trigger Determined By

This option defines how BLAZE recognizes an incoming external trigger.

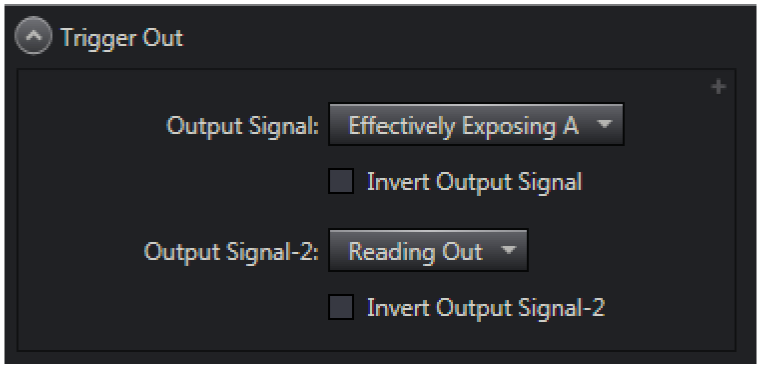
Valid values are:

- Rising Edge;
  BLAZE acknowledges all triggers on their rising edge.
- Falling Edge;
  BLAZE acknowledges all triggers on their falling edge.
- Alternating Edge – Rising;
  BLAZE acknowledges the first trigger on its rising edge, and all subsequent triggers on each edge transition.
- Alternating Edge – Falling.
  BLAZE acknowledges the first trigger on its falling edge, and all subsequent triggers on each edge transition.

11.1.4 Trigger Out

This section provides information about SeNsR parameters accessed on the Trigger Out expander. See Figure 11-4.

Figure 11-4: Typical SeNsR Mode: Trigger Out Expander



11.1.4.1 Output Signal

This configures the logical Output Signal timing of BLAZE events.

Valid values are:

- Acquiring;
  When selected, Output Signal is high when BLAZE is acquiring or ready to receive the first trigger.
- Always High;
  When selected, Output Signal is always high.
- Effectively Exposing Alternation;
  When selected, Output Signal is high when exposing Spectrum 1, and low when exposing Spectrum 2. See Figure 2-4, on page 19.
- Exposing;
  When selected, Output Signal is high when the sensor is exposed as requested.
- Reading Out;
  When selected, Output Signal is high when the sensor is reading out.
- Shifting Under Mask;
  When selected, Output Signal is high when shifting acquired data between the storage strip and the active/imaging strip.
- Shutter Open;
  When selected, Output Signal is high when the shutter is open.
- Waiting for Trigger.
  When selected, Output Signal is high when BLAZE is waiting for an incoming trigger.

11.1.4.2 Invert Output Signal

Selecting this option inverts the Output Signal such that timing is represented by a low/logic-0 level signal.

11.1.4.3 Output Signal-2

This configures the logical Output Signal timing of BLAZE events.

Valid values are:

- Acquiring;

  When selected, Output Signal-2 is high when BLAZE is acquiring or ready to receive the first trigger.
- Always High;

  When selected, Output Signal-2 is always high.
- Effectively Exposing Alternation;

  When selected, Output Signal-2 is high when exposing Spectrum 1, and low when exposing Spectrum 2. See Figure 2-4, on page 19.
- Exposing;

  When selected, Output Signal-2 is high when the sensor is exposed as requested.
- Reading Out;

  When selected, Output Signal-2 is high when the sensor is reading out.
- Shifting Under Mask;

  When selected, Output Signal-2 is high when shifting acquired data between the storage strip and the active/imaging strip.
- Shutter Open;

  When selected, Output Signal-2 is high when the shutter is open.
- Waiting for Trigger.

  When selected, Output Signal-2 is high when BLAZE is waiting for an incoming trigger.

11.1.4.4 Invert Output Signal-2

Selecting this option inverts the Output Signal-2 such that timing is represented by a low/logic-0 level signal.

11.2 Experiment Timing

For many experiments, the acquisition of quality/useful data is dependent on precise synchronization with external experiment events. This is particularly true for SeNsR applications which rely on the synchronization between the experiment and BLAZE in order to accurately extract the signal from a noisy background.

Using the SYNC input on the rear of BLAZE, externally-generated trigger pulses can be used to control:

- Shutter Operation;

REFERENCES:

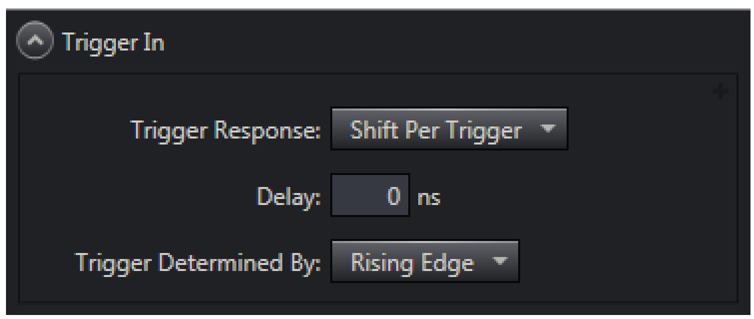
Refer to Chapter 13, Shutter Control, on page 139 for detailed information about each available shutter mode.

- Data Readout.

This section describes how to configure BLAZE to use incoming trigger pulses to precisely control experiment synchronization in SeNsR mode.

Figure 11-5 illustrates a typical Trigger In expander.

Figure 11-5: Typical Trigger In Expander: SeNsR Mode



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Depending on the specific experiment, two parameters are used to configure BLAZE'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.

11.2.1 Trigger Response

The Trigger Response parameter defines how BLAZE 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**.

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.

11.2.1.1 No Response

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

In this mode, BLAZE 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 4 μs and is limited by the time required to shift data between the storage strip and the active/imaging strip.

Supported Shutter modes are:

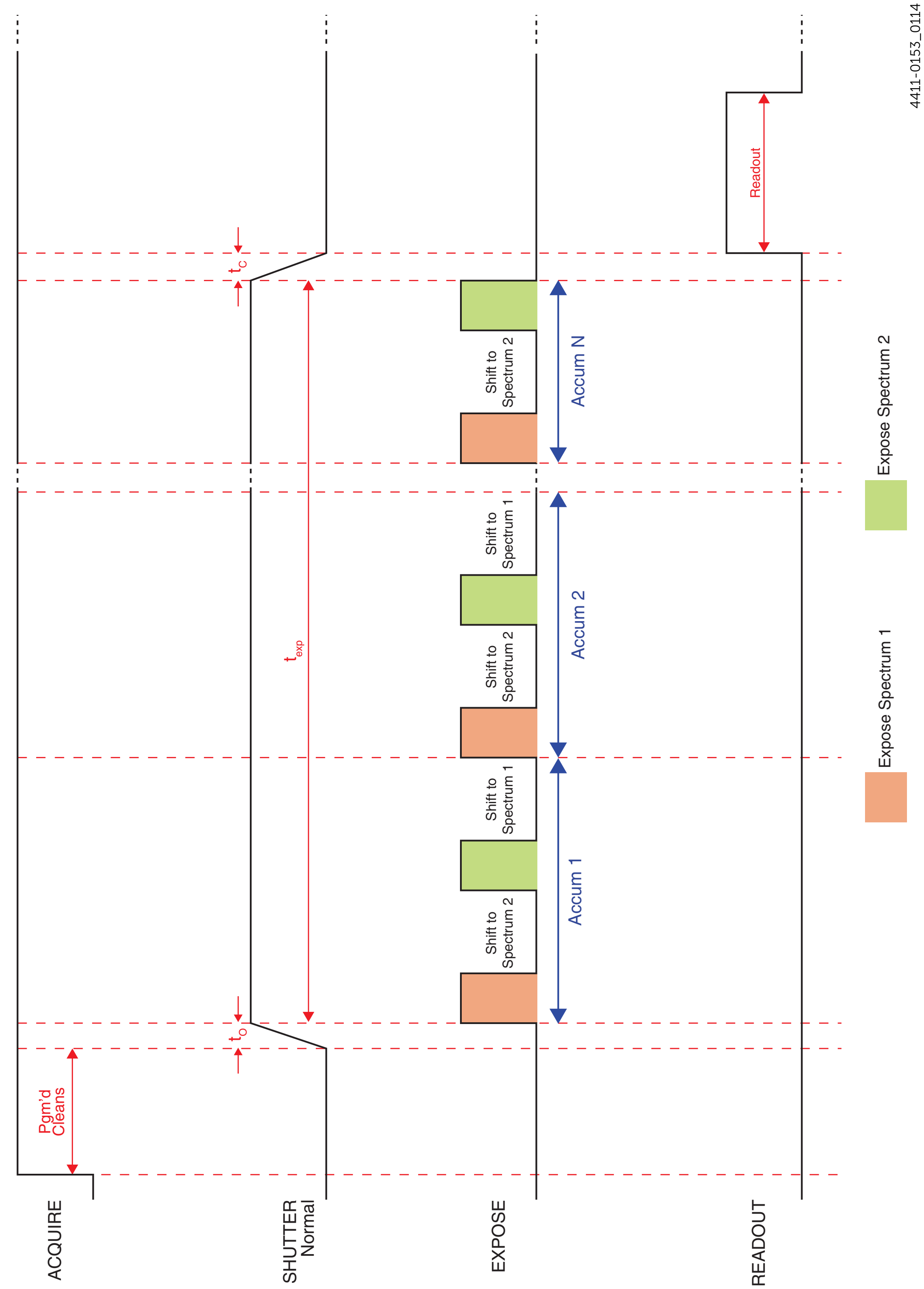
- **Normal**;
- **Always Closed**;
- **Always Open**.

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

11.2.1.1.1 Normal

Figure 11-6 illustrates the timing diagram for No Response mode combined with Normal shutter mode.

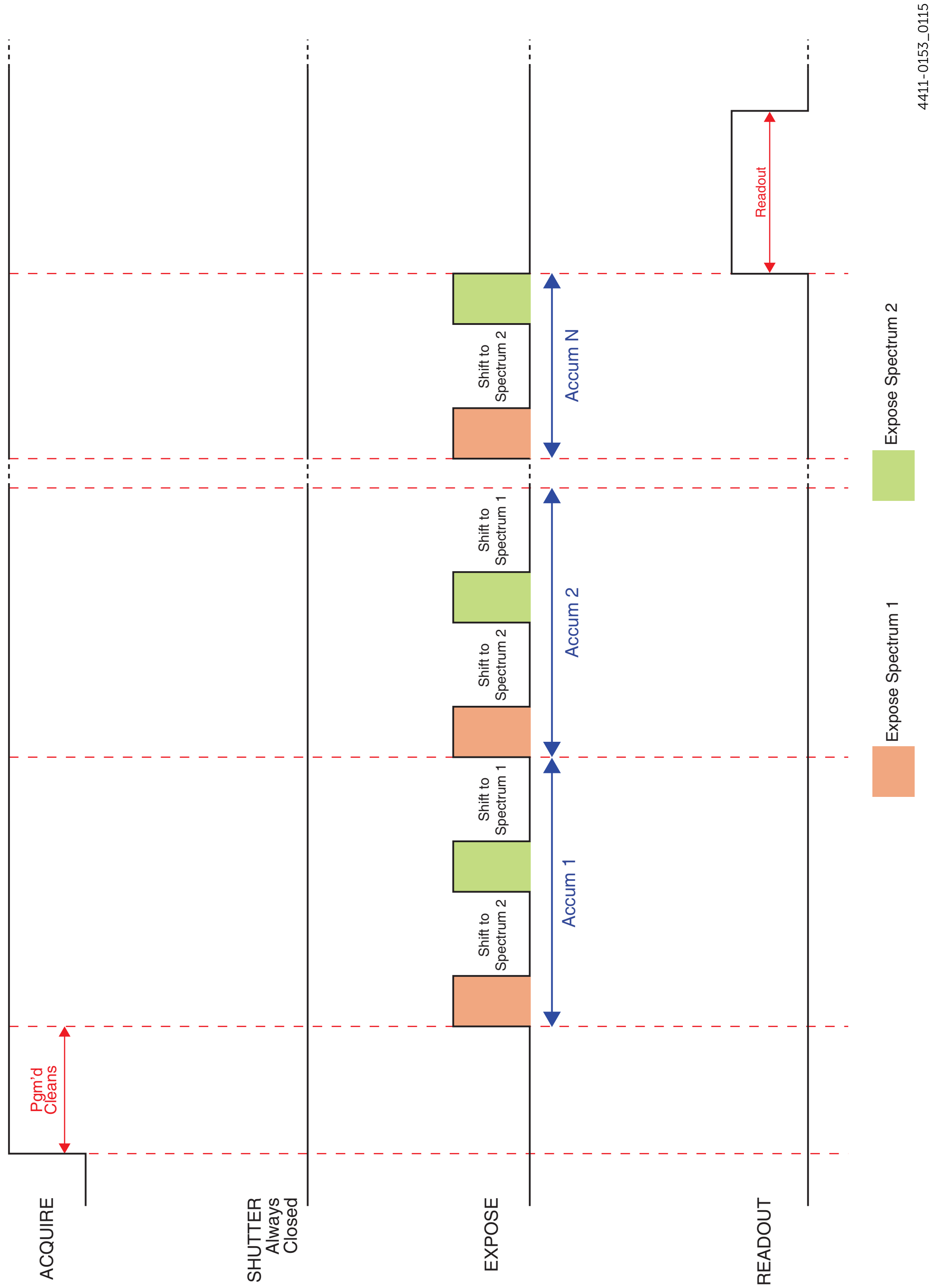
Figure 11-6: SeNsR Timing Diagram: No Response, Normal



11.2.1.1.2 Always Closed

Figure 11-7 illustrates the timing diagram for No Response mode combined with Always Closed shutter mode.

Figure 11-7: SeNsR Timing Diagram: No Response, Always Closed

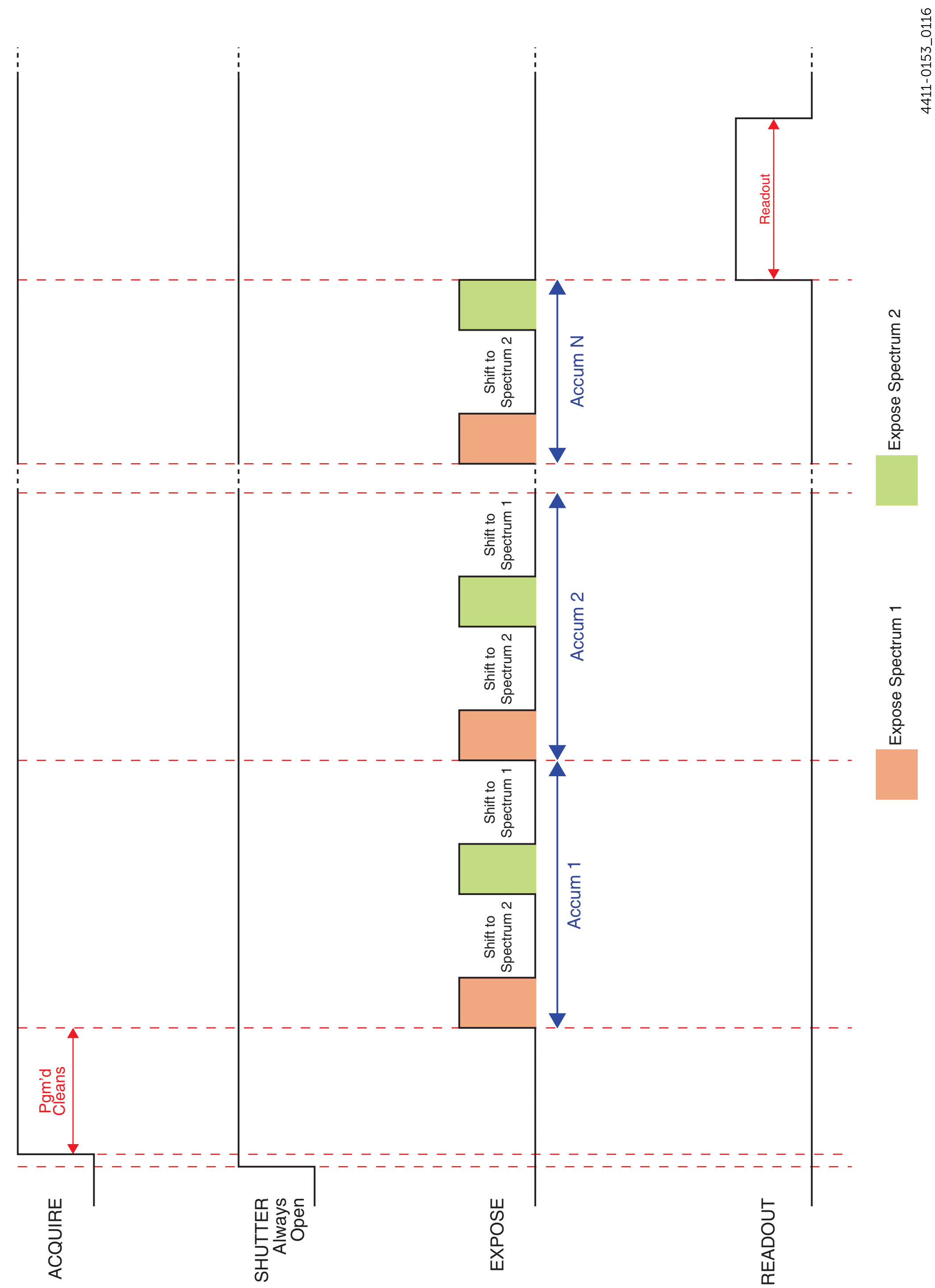


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

11.2.1.1.3 Always Open

Figure 11-8 illustrates the timing diagram for No Response mode combined with Always Open shutter mode.

Figure 11-8: SeNsR 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.)

11.2.1.2 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:

- SeNsR 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.

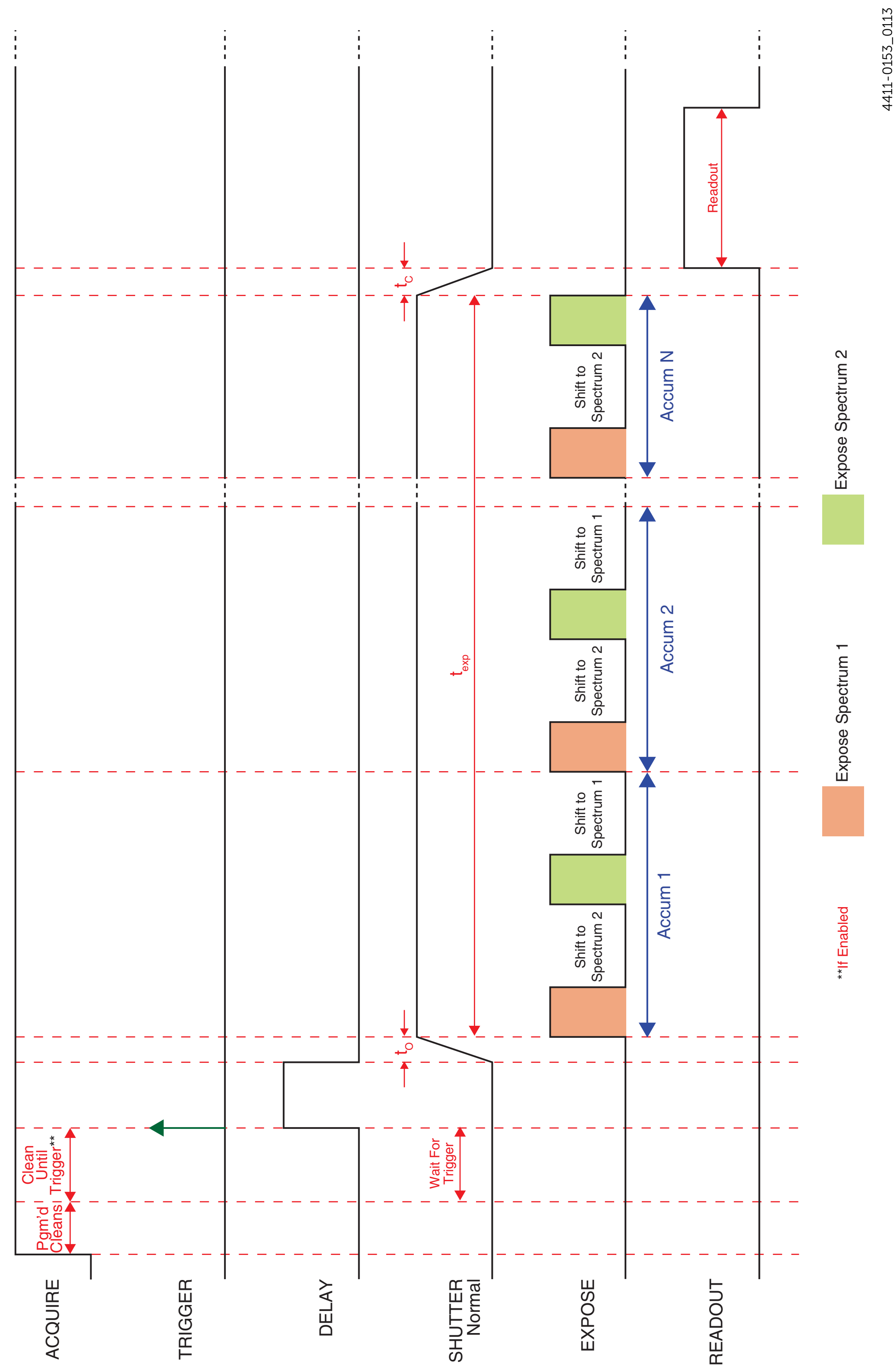
NOTES:

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 57 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

11.2.1.2.1 Normal

Figure 11-9 illustrates the timing diagram for Start on Single Trigger mode combined with Normal shutter mode.

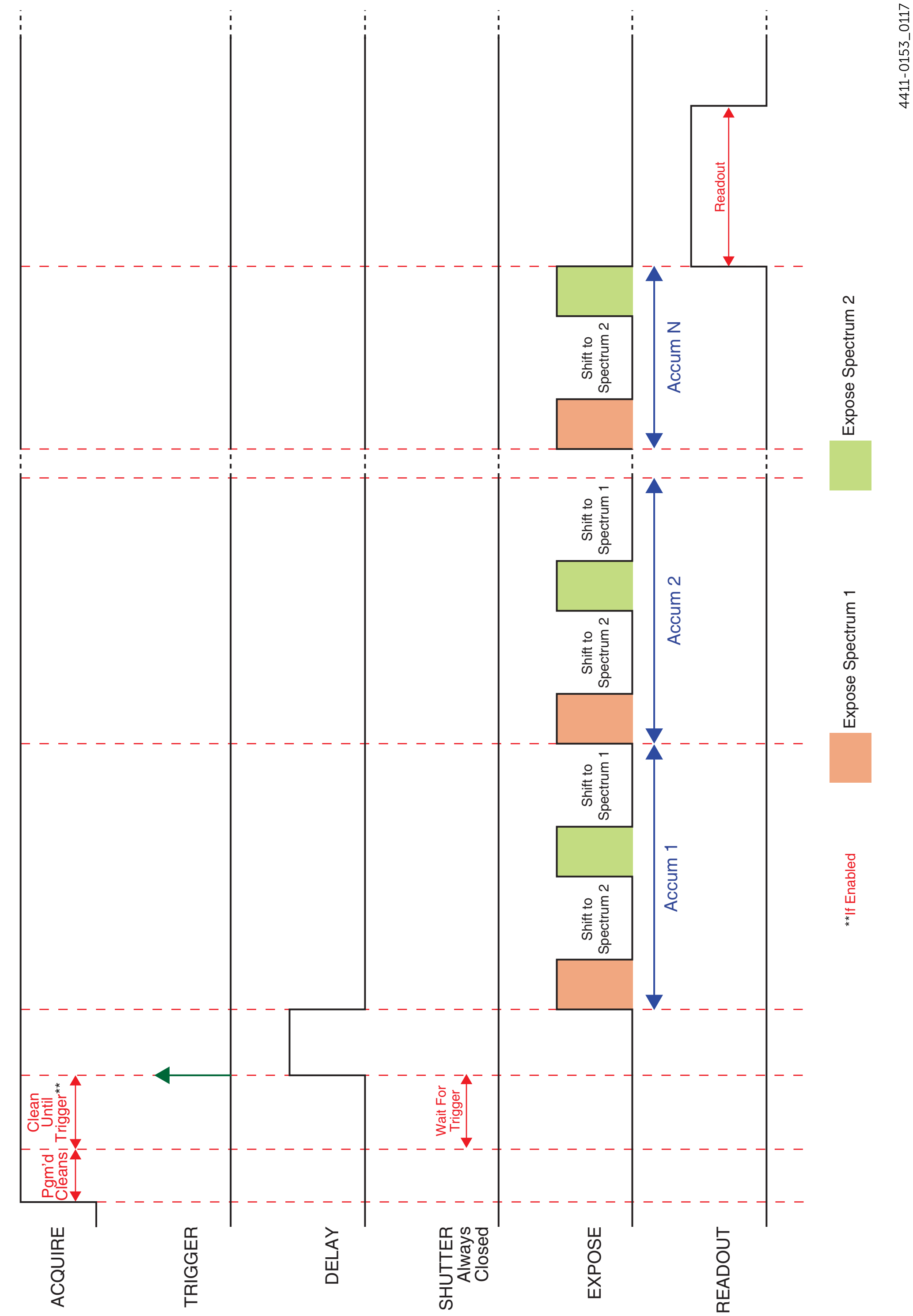
Figure 11-9: SeNsR Timing Diagram: Start on Single Trigger, Normal



11.2.1.2.2 Always Closed

Figure 11-10 illustrates the timing diagram for Start on Single Trigger mode combined with Always Closed shutter mode.

Figure 11-10:SeNsR Timing Diagram: Start on Single Trigger, Always Closed

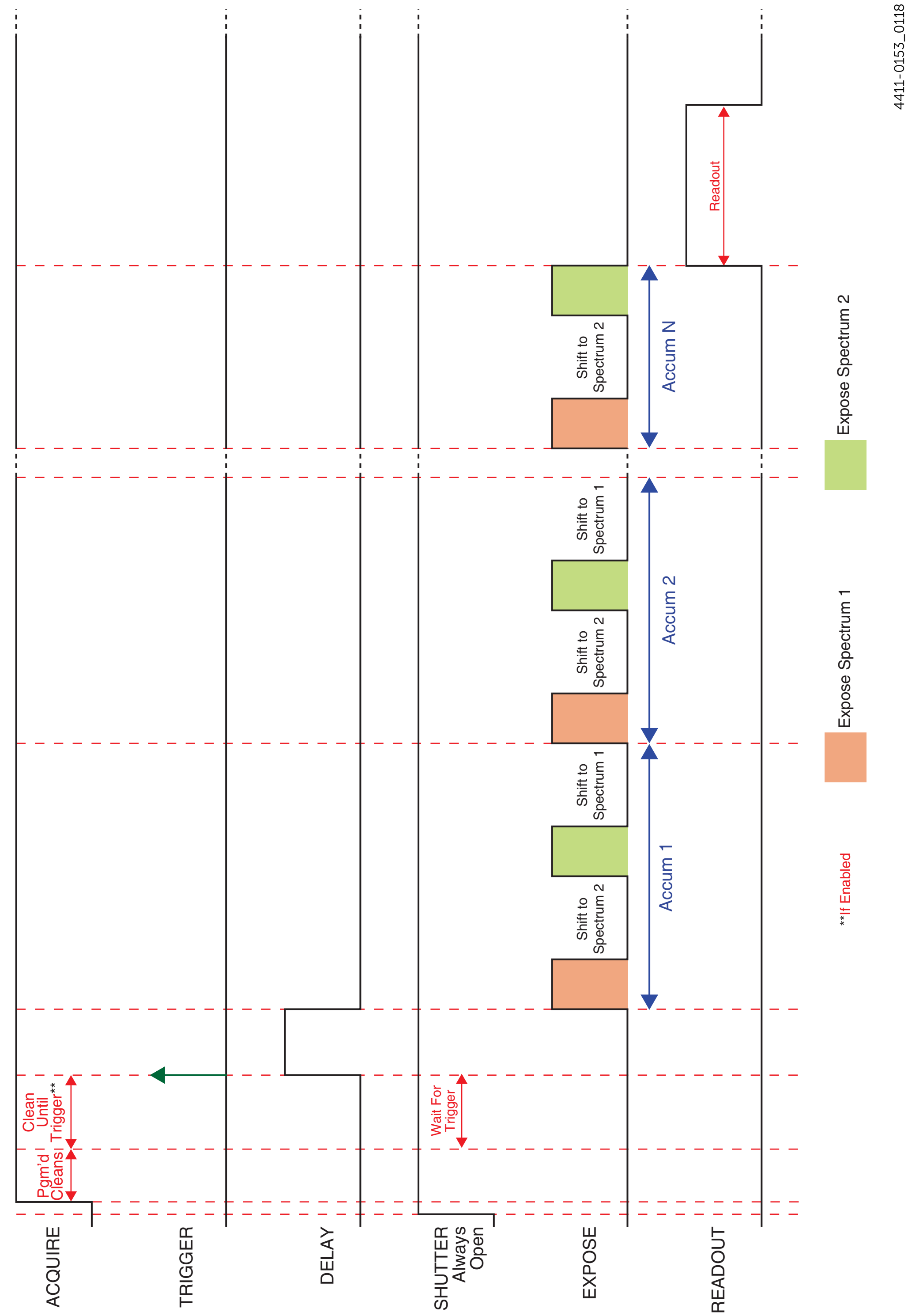


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

11.2.1.2.3 Always Open

Figure 11-11 illustrates the timing diagram for Start on Single Trigger mode combined with Always Open shutter mode.

Figure 11-11: SeNsR Timing Diagram: Start on Single Trigger, Always Open

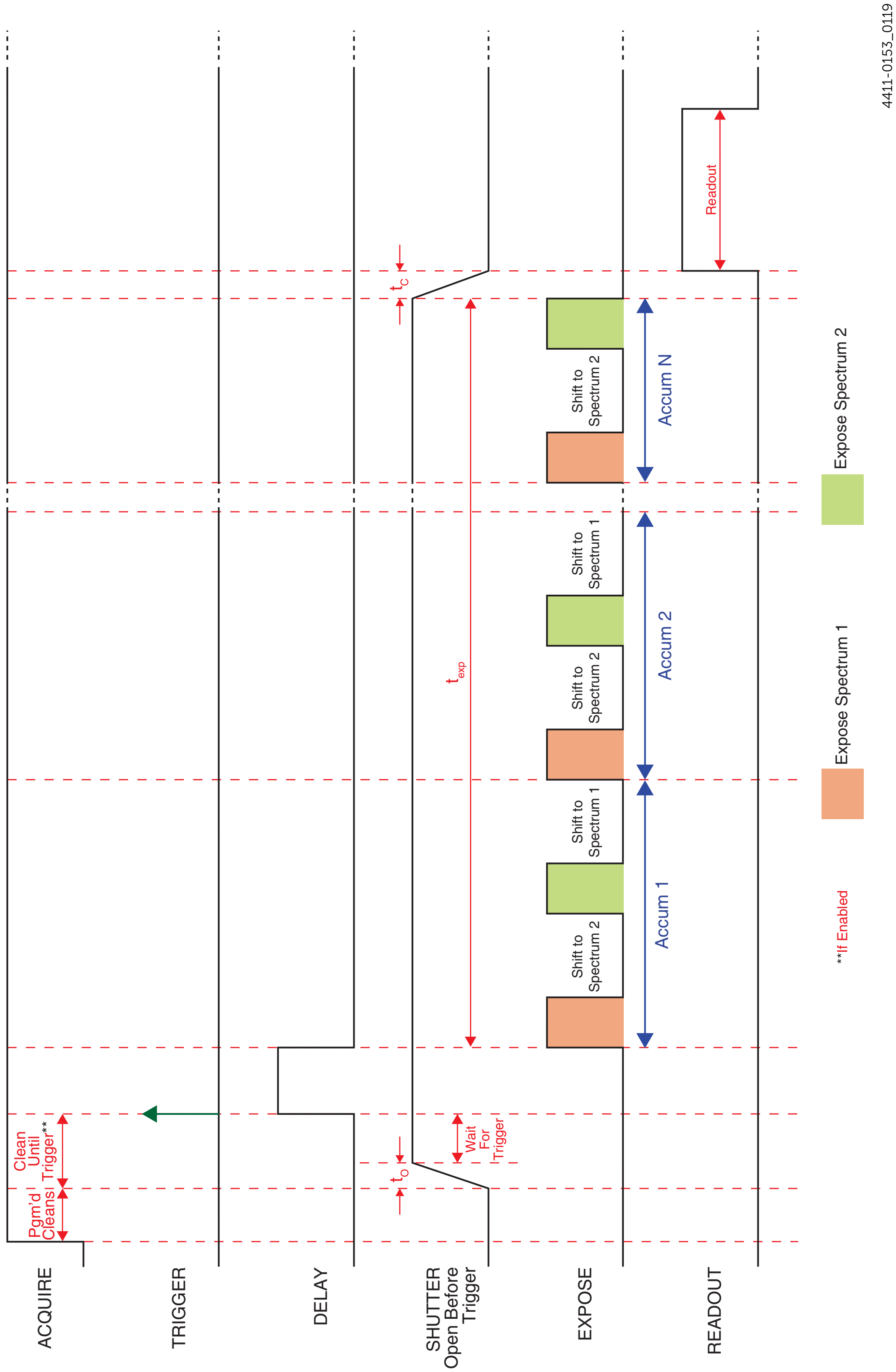


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.)

11.2.1.2.4 Open Before Trigger

Figure 11-12 illustrates the timing diagram for Start On Single Trigger mode combined with Open Before Trigger shutter mode.

Figure 11-12: SeNsR Timing Diagram: Start On Single Trigger, Open Before Trigger



11.2.1.3 Readout Per Trigger

When configured for Readout Per Trigger, BLAZE requires one trigger to initiate an entire series of Exposure/Shift cycles between the two storage areas and the active/exposing area, as illustrated in Figure 2-4 on page 19.

When Acquire or Run is selected:

- The active shutter is opened;
- BLAZE waits for an incoming external trigger;
- Once the incoming external trigger has been received, BLAZE acquires data using the configured Exposure Time by exposing the active/imaging area and shifting acquired data as illustrated in Figure 2-4 on page 19.

After the required series of exposures has been acquired, the active shutter closes and the CCD is read out at normal speeds. Once readout is complete, BLAZE 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.

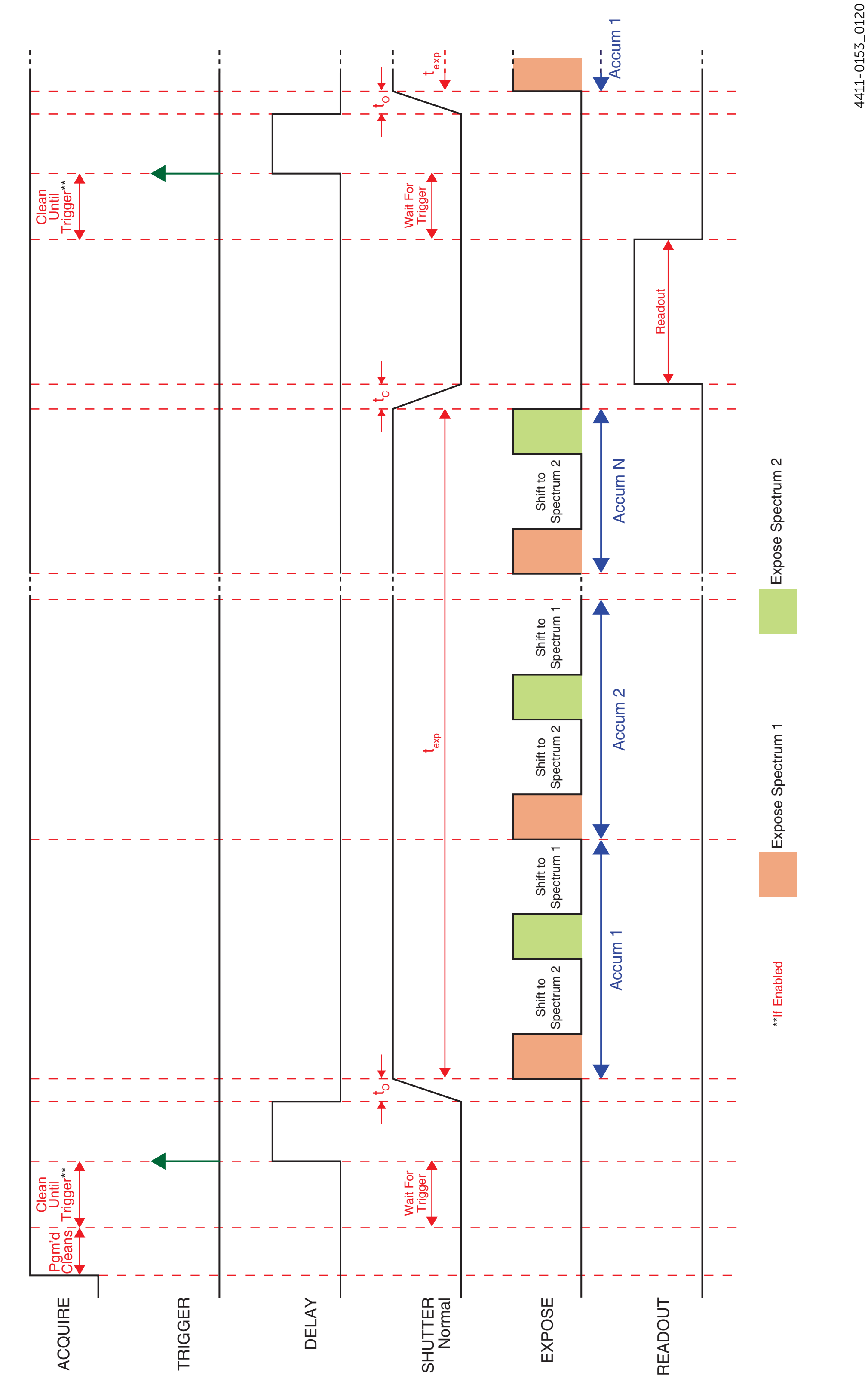
NOTES:

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 57 for additional information.
2. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

11.2.1.3.1 Normal

Figure 11-13 illustrates the timing diagram for Readout Per Trigger mode combined with Normal shutter mode.

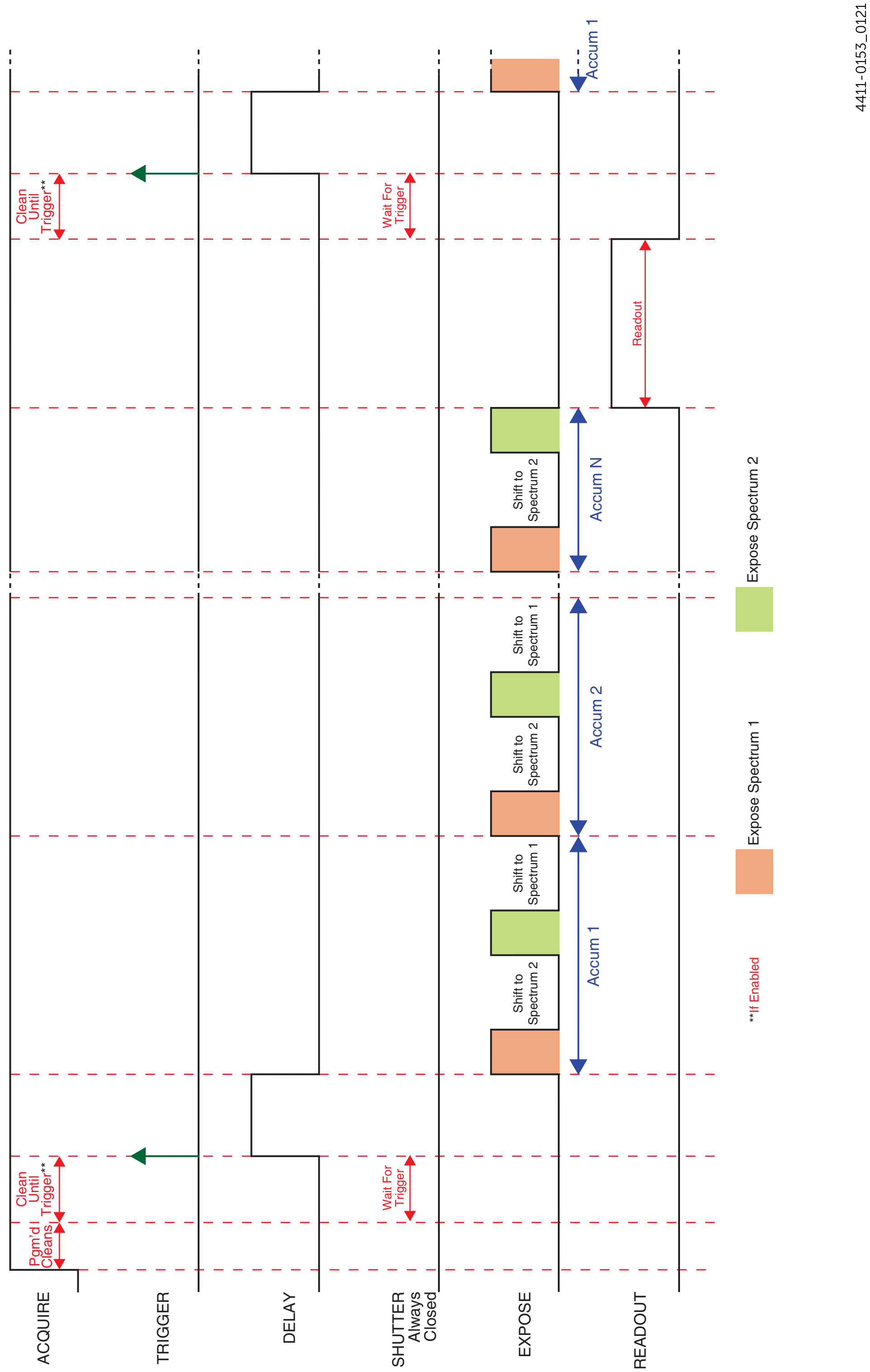
Figure 11-13: SeNsR Timing Diagram: Readout Per Trigger, Normal



11.2.1.3.2 Always Closed

Figure 11-14 illustrates the timing diagram for Readout Per Trigger mode combined with Always Closed shutter mode.

Figure 11-14:SeNsR Timing Diagram: Readout Per Trigger, Always Closed

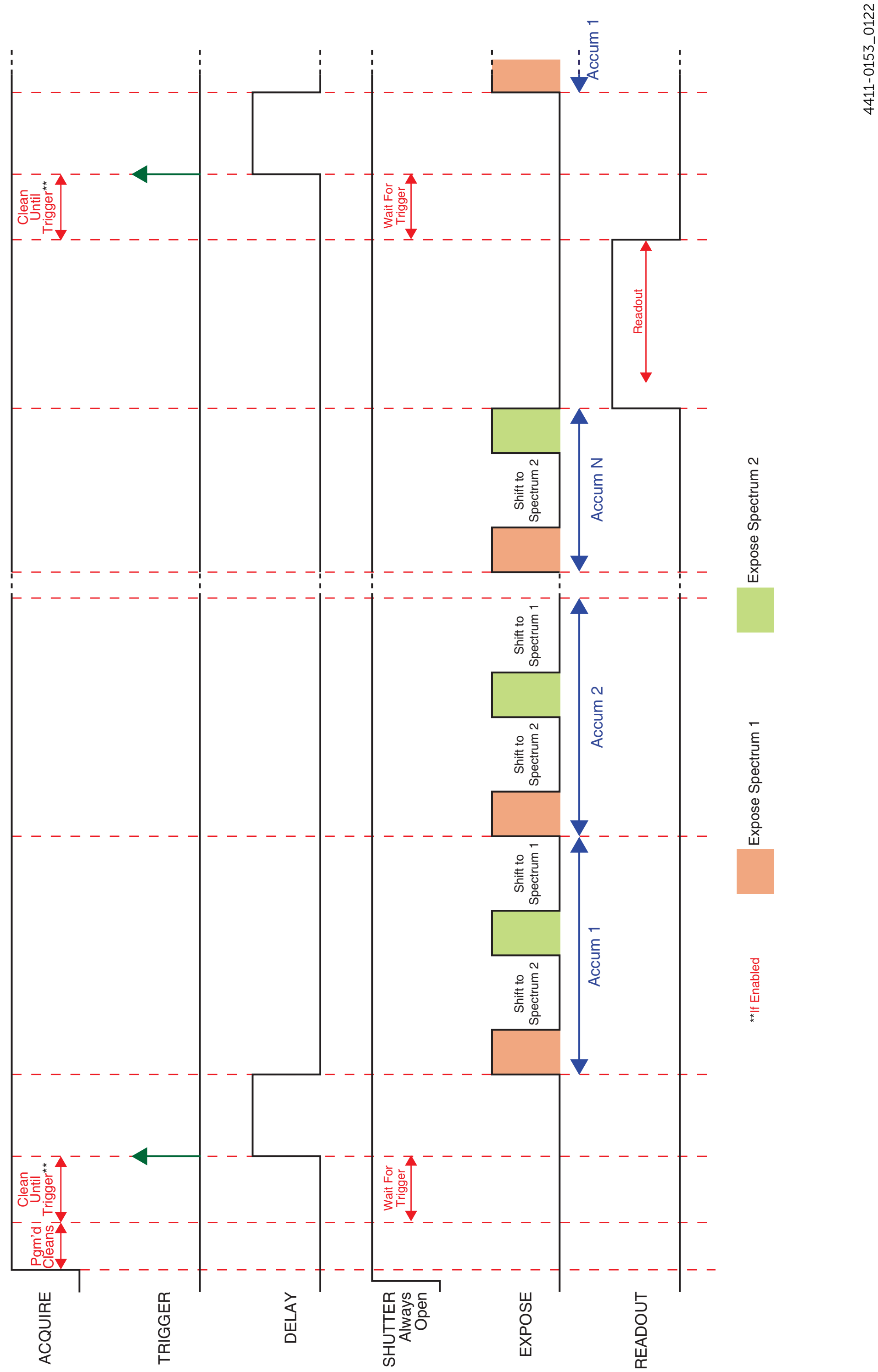


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

11.2.1.3.3 Always Open

Figure 11-15 illustrates the timing diagram for Readout Per Trigger Pulse mode combined with Always Open shutter mode.

Figure 11-15:SeNsR Timing Diagram: Readout Per Trigger, Always Open

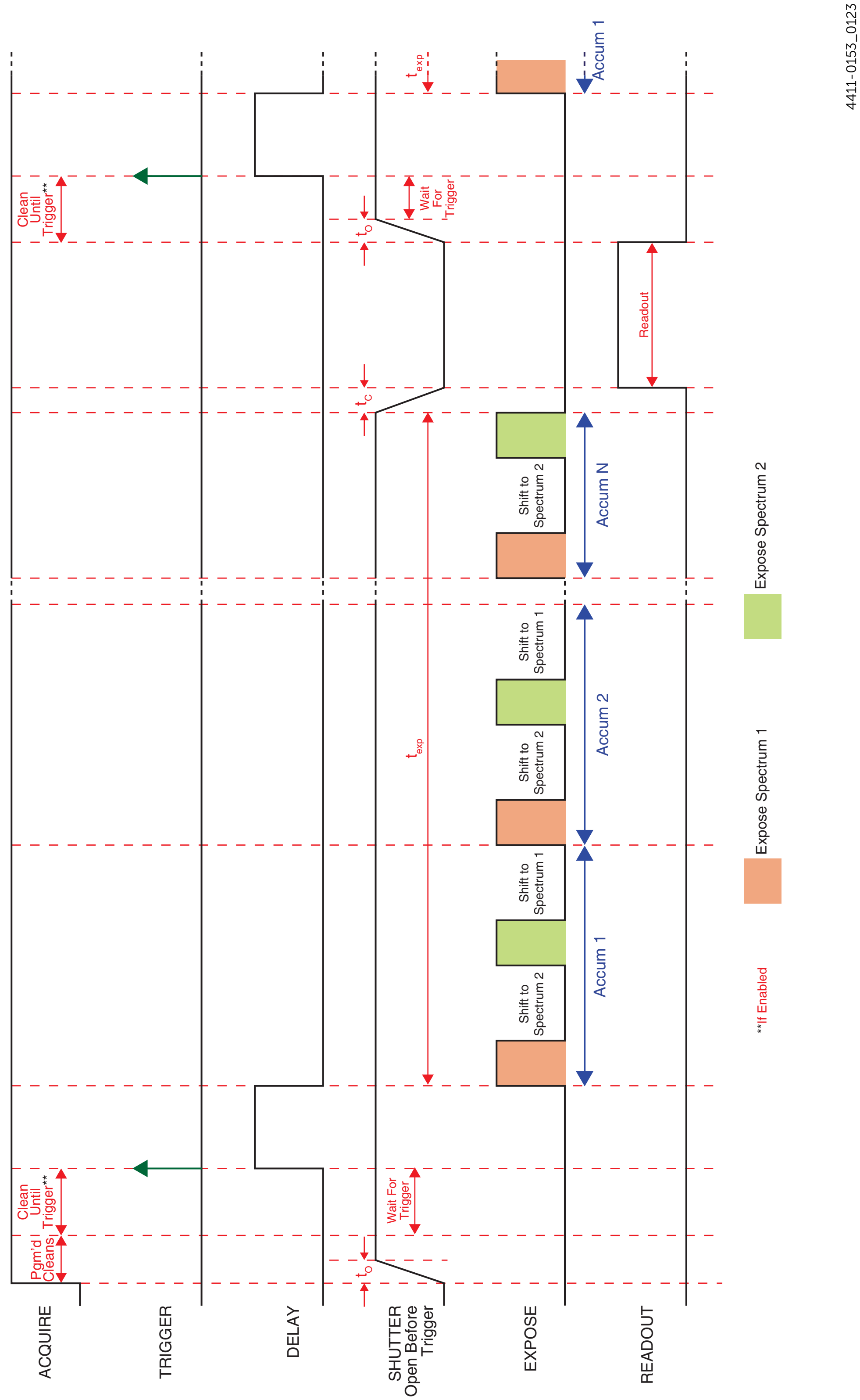


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) Open Before Trigger is related.

11.2.1.3.4 Open Before Trigger

Figure 11-16 illustrates the timing diagram for Readout Per Trigger mode combined with Open Before Trigger shutter mode.

Figure 11-16:SeNsR Timing Diagram: Readout Per Trigger, Open Before Trigger



11.2.1.4 Shift Per Trigger

When configured for Shift Per Trigger, each Exposure/Shift cycle throughout the acquisition is triggered independently by 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.

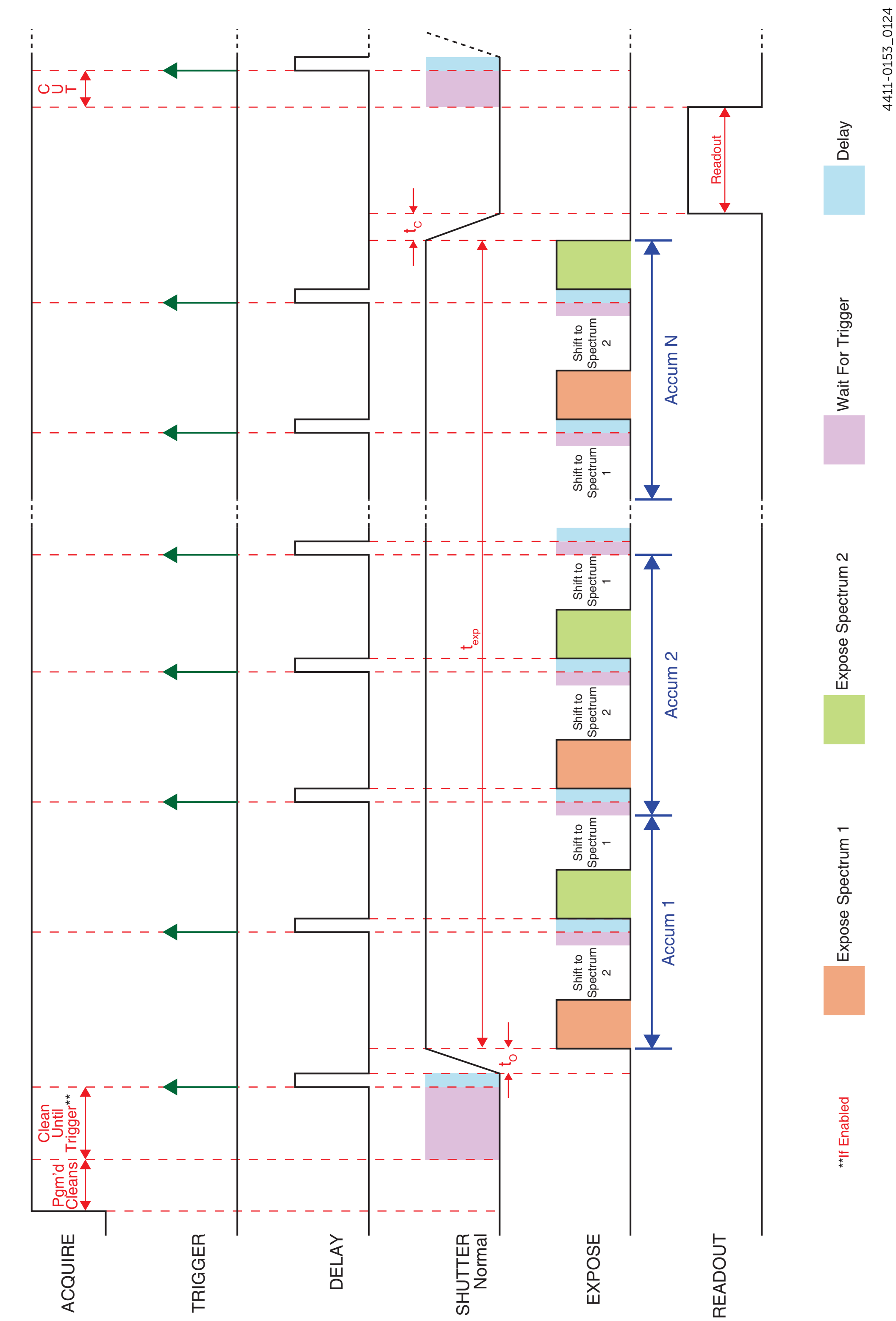
NOTES:

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 57 for additional information.
2. Although the four Shutter modes listed above are supported by BLAZE in SeNsR Mode, for most applications, Open Before Trigger is the preferred Shutter mode for Shift Per Trigger applications.
3. In all timing diagrams, Trigger Determined By Rising Edge is illustrated.

11.2.1.4.1 Normal

Figure 11-17 illustrates the timing diagram for Shift Per Trigger mode combined with Normal shutter mode.

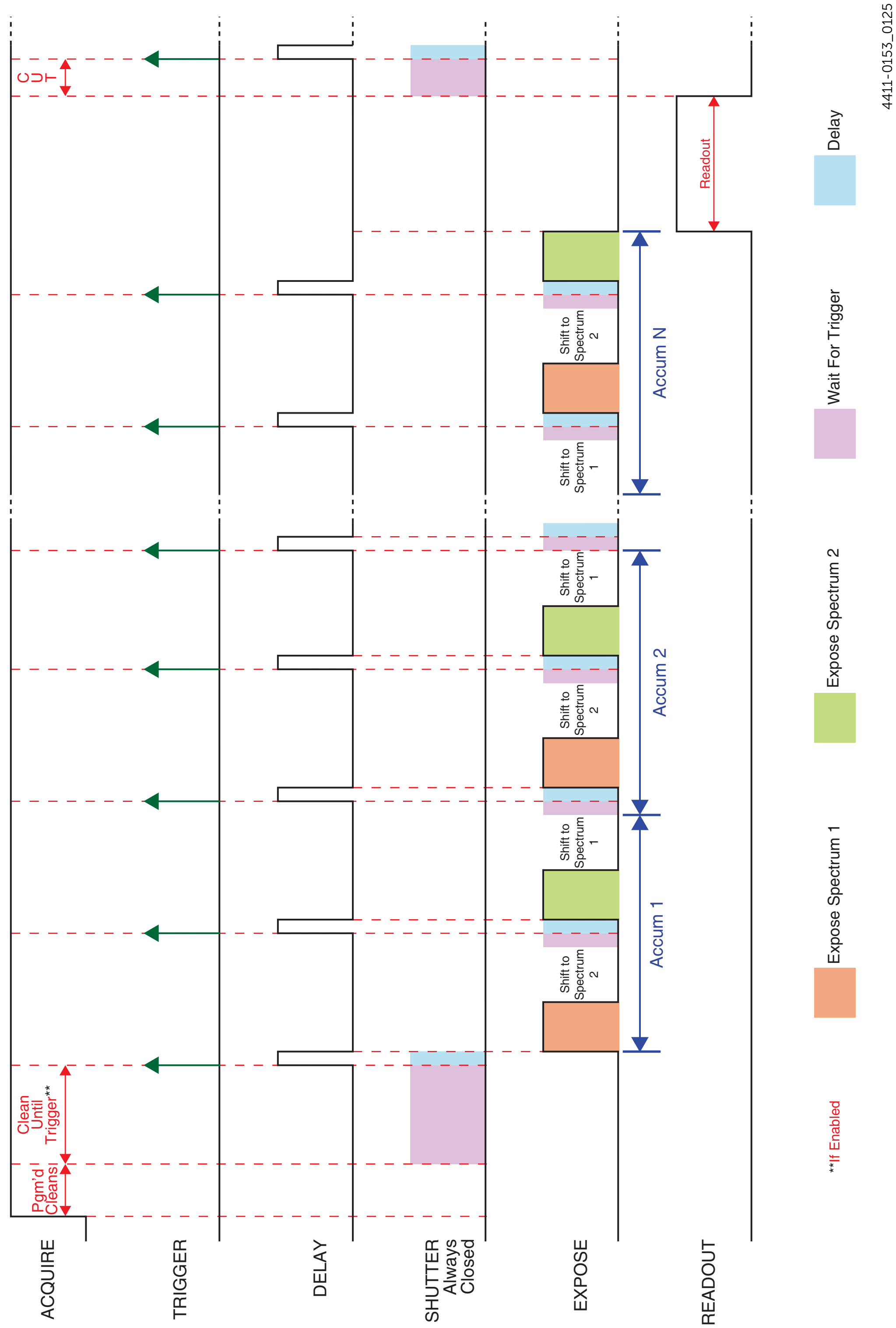
Figure 11-17: SeNsR Timing Diagram: Shift Per Trigger, Normal



11.2.1.4.2 Always Closed

Figure 11-18 illustrates the timing diagram for Shift Per Trigger mode combined with Always Closed shutter mode.

Figure 11-18:SeNsR Timing Diagram: Shift Per Trigger, Always Closed

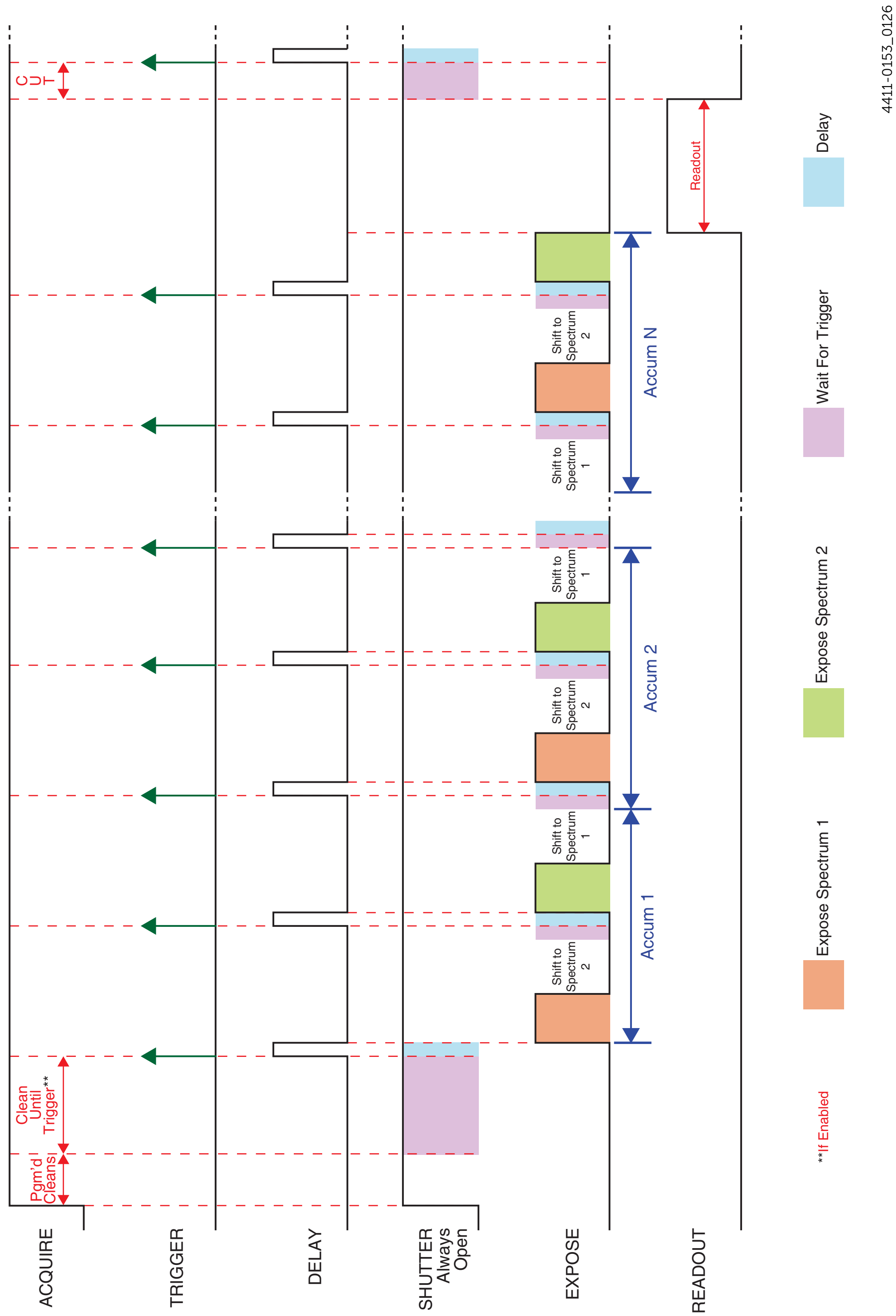


This mode is primarily used when acquiring a dark reference file. However, BLAZE typically runs at such a low temperature that a dark reference file is often unnecessary.

11.2.1.4.3 Always Open

Figure 11-19 illustrates the timing diagram for Shift Per Trigger mode combined with Always Open shutter mode.

Figure 11-19:SeNsR Timing Diagram: Shift Per Trigger, Always Open

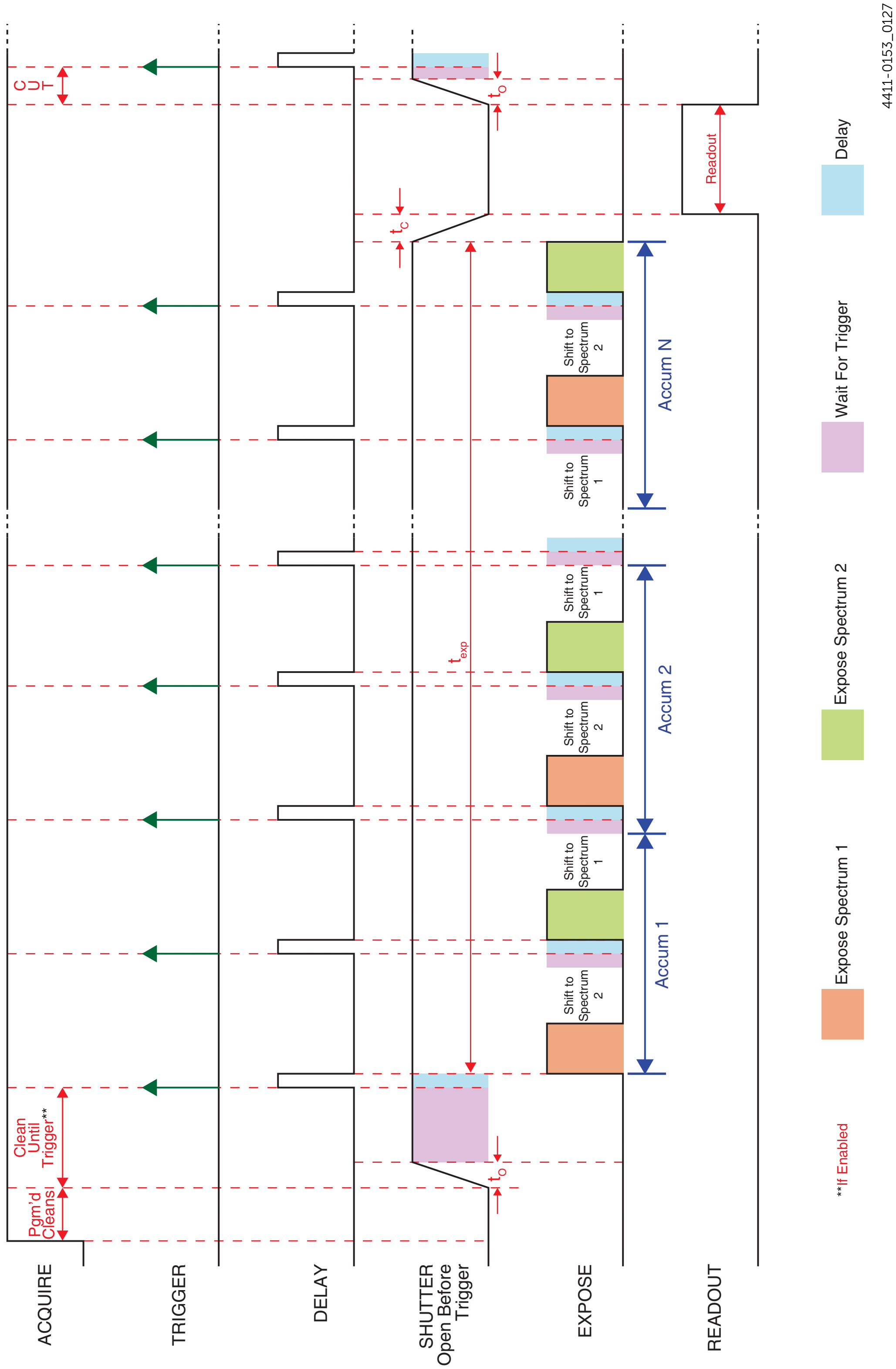


This mode is typically used when an experiment does not support waiting for the shutter to open. Ideally, the only light generated by the experiment is the signal of interest (e.g., a dark chamber with a spark discharge.) Open Before Trigger is related.

11.2.1.4.4 Open Before Trigger

Figure 11-20 illustrates the timing diagram for Shift Per Trigger mode combined with Open Before Trigger shutter mode.

Figure 11-20:SeNsR Timing Diagram: Shift Per Trigger, Open Before Trigger



11.2.2 Trigger Determined By

When using an external trigger to initiate a readout, BLAZE 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;

  BLAZE 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 11.2.1, Trigger Response, on page 114 for complete information about configuring incoming trigger responses.

  NOTE:

  If BLAZE is busy when a subsequent trigger pulse is received, the trigger is ignored.

- Falling Edge.

  BLAZE 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 11.2.1, Trigger Response, on page 114 for complete information about configuring incoming trigger responses.

  NOTE:

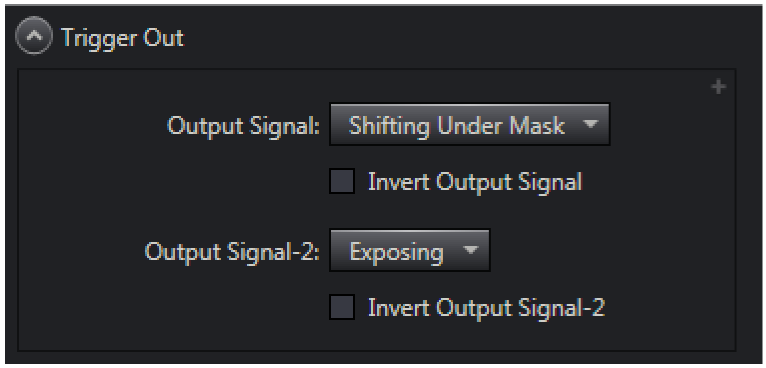
  If BLAZE is busy when a subsequent trigger pulse is received, the trigger is ignored.

11.3 Trigger Out

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

Two trigger out pulses are configured on the Trigger Out expander, shown in Figure 11-21.

Figure 11-21: Typical Trigger Out Expander



4411-0153_0034

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

- Acquiring;
  The associated output signal is high when BLAZE 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 SeNsR shifts are occurring.
- Shutter Open;
  The associated output signal is high when the shutter is open.
- Waiting for Trigger.
  The associated output signal when BLAZE 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.

Chapter 12: 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.

12.1 Hardware Binning

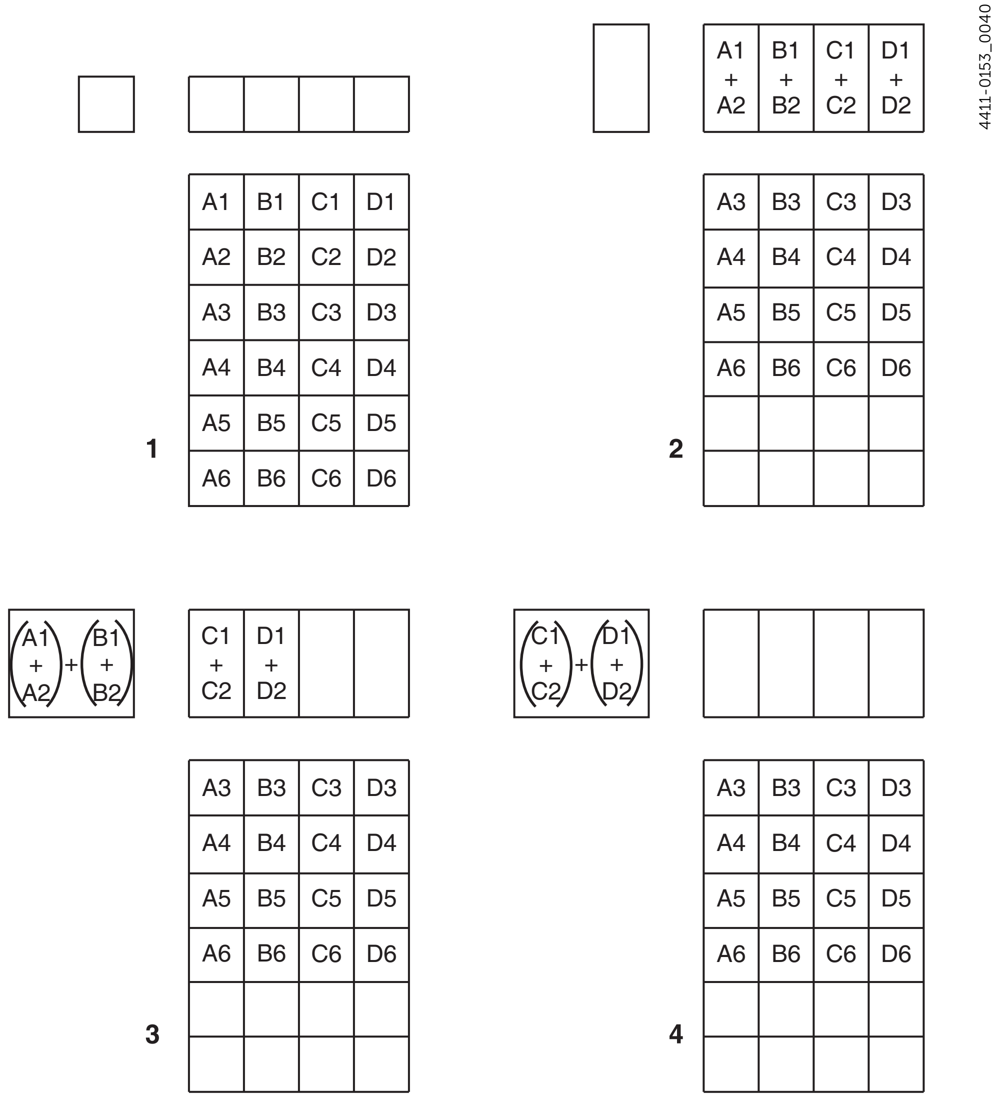
Hardware binning is performed on the CCD array before the signal is read out of the output amplifier. For signal levels that are readout noise limited this method improves S/N ratio linearly with the number of pixels grouped together. For signals large enough to render the camera photon shot noise limited, 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 BLAZE is configured for 2-port readout, all binning regions must be symmetrical about the vertical center-line of the CCD.

Figure 12-1 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.

Figure 12-1: 2 × 2 Binning



12.2 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 pixels binned. Unfortunately, with a high number of pixels binned, 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 (e.g., absorbance spectroscopy,) 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.

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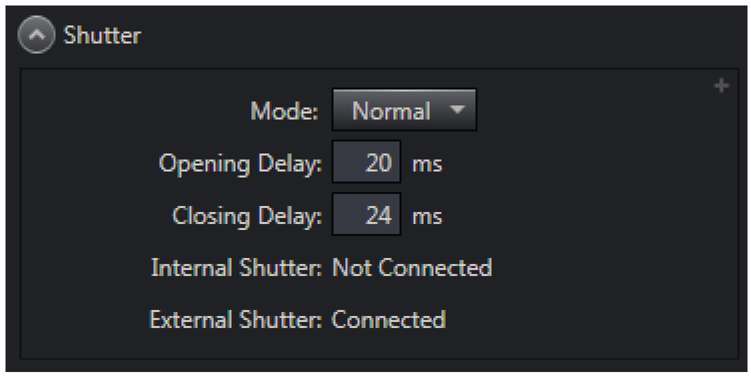
Chapter 13: Shutter Control

This chapter provides information about the configuration and control of an external shutter that is connected to a BLAZE camera.

13.1 Configuration

Shutter information is configured within LightField on the Shutter expander. Figure 13-1 illustrates a typical Shutter expander when an external shutter has been installed.

Figure 13-1: Typical Shutter Expander: External Shutter Installed



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13.1.1 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 BLAZE 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 170 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, BLAZE 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 BLAZE 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.

13.1.2 Opening Delay

Specifies, in milliseconds, the length of time BLAZE is to wait for the shutter to open.

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

13.1.3 Closing Delay

Specifies, in milliseconds, the length of time BLAZE is to wait for the shutter to close.

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

13.2 Internal Shutter

NOTE:

For BLAZE, this status will always be Not Connected.

13.3 External Shutter

Status of the external shutter.

BLAZE automatically detects when an external shutter has been connected.

CAUTION!

In order to prevent potential permanent damage to either the BLAZE 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 27 to a BLAZE. Refer to Contact Information on page 170 for complete information.

13.4 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 BLAZE 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 27 to a BLAZE. Refer to Contact Information on page 170 for complete information.

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

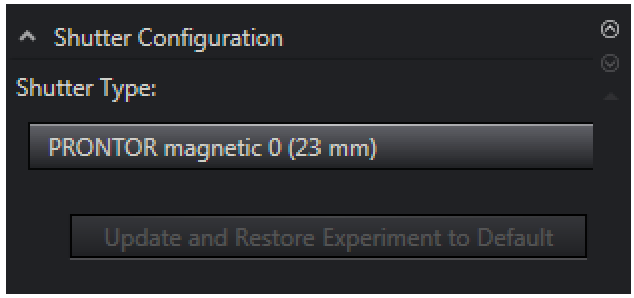
When using a different supported shutter (refer to Table 2-4, Supported External Shutters, on page 27 for a list of supported shutters,) before beginning to configure parameters or acquiring data, the correct device must be selected via the Shutter Configuration Add-In, which is accessed within LightField 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 13-2 illustrates a typical Shutter Configuration add-in with the default shutter selected.

Figure 13-2: Typical Shutter Configuration Add-In: Default External Shutter



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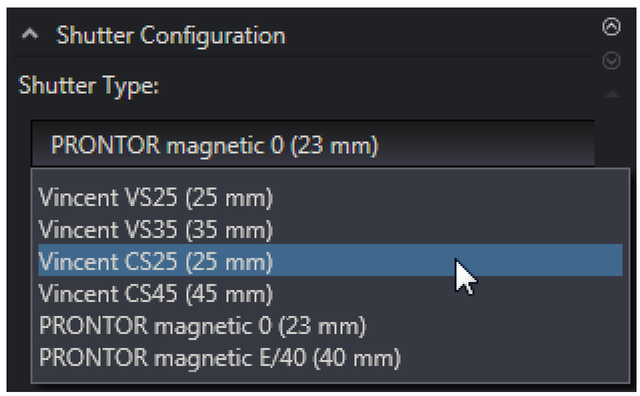
To select an alternative, supported shutter, click on the Shutter Type: field to display a pull-down menu of all supported shutters, and click on the shutter that is being used. For example, the Vincent CS25 (25 mm) shutter is to be used, as shown in Figure 13-3.

Figure 13-3: Typical Shutter Type Menu



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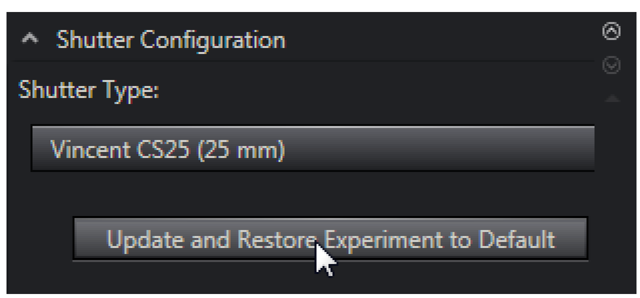
Once the new shutter has been selected, the Update and Restore Experiment to Default action is then enabled. See Figure 13-4.

Figure 13-4: Typical Update Shutter Type Action



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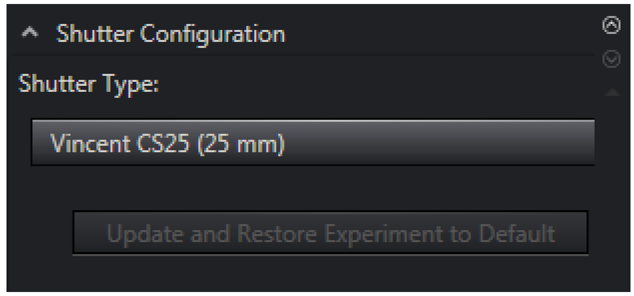
Click on Update and Restore Experiment to Default to update the external shutter information within the BLAZE system. The Shutter Type: now reflects the selected shutter, similar to that shown in Figure 13-5.

Figure 13-5: Typical Updated Shutter: Non-Default Shutter Selected



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 BLAZE 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	14.3 lbs [6.5 kg]

A.1.1 Vacuum Window

SI-UV fused-silica quartz (0.125"/3.17 mm thick)

A.2 Camera Specifications

Refer to Table A-2 for CCD specifications for BLAZE detectors.

Table A-2: BLAZE CCD Specifications[a] (Sheet 1 of 2)

Specification	100B/BR/BR/ LD/eXcelon	100HR/HR eXcelon	400B/BR/BR/ LD/eXcelon	400HR/HR eXcelon
CCD	Proprietary		Proprietary	
Resolution	1340 x 100		1340 x 400	
Pixel Size	20 µm x 20 µm		20 µm x 20 µm	
Imaging Area	26.8 mm x 2 mm		26.8 mm x 8 mm	
Spectra/s[b] (full frame)	~2000 fps	~1500 fps	~600 fps	~530 fps
Readout Amplifiers (Ports)	4 (available 2 at a time)		4 (available 2 at a time)	
ADC Speed/16 bits[c]	100 kHz, 1 MHz, 5 MHz, 10 MHZ, 16 MHz		100 kHz, 1 MHz, 5 MHz, 10 MHZ, 16 MHz	

Table A-2: BLAZE CCD Specifications[a] (Sheet 2 of 2)

Specification	100B/BR/BR/ LD/eXcelon	100HR/HR eXcelon	400B/BR/BR/ LD/eXcelon	400HR/HR eXcelon
Vertical Shift Rate[d]	4 μsec/row		4 μsec/row	
Read Noise per Port	2.8 e^- rms @ 100 kHz 6 e^- rms @ 1 MHz 20 e^- rms @ 4 MHz			
Non-linearity	< 2% @ 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 BLAZE data sheets available for download from www.princetoninstruments.com.
b. @ 16 MHz, 2-port readout, full vertical binning
c. Per port
d. Software programmable

NOTE:

High-Rho CCDs are particularly sensitive to cosmic ray events. Cosmic ray events can make the read noise appear higher if they are not excluded from the data set when the noise is calculated. They can also make the effective dark current higher. Teledyne Princeton Instruments recommends performing longer exposures as a sum of shorter exposures in order to facilitate the removal cosmic ray hits from the data set.

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]	-100 °C
Deepest Cooling Temperature	Air	Less than -90 °C
	Liquid[a]	-100 °C
Precision	–	±0.05 °C

a. External coolant circulator required.

A.3 Power Specifications

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

Power to the camera is switched on and off using the toggle 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 BLAZE camera will void the camera warranty. For specific power supply requirements, contact Teledyne Princeton Instruments. Refer to Contact Information on page 170 for complete information.

Refer to Table A-4 for power specifications for the external BLAZE 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: BLAZE 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 BLAZE camera.

Where BLAZE is within an enclosure, >30 cfm air circulation and heat dissipation of 200 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 shutters supported by BLAZE.

Table A-7: BLAZE External Shutter Specifications

Parameter	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 BLAZE 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 27 to a BLAZE. Refer to Contact Information on page 170 for complete information.

External shutters must be equipped with a compatible shutter connector in order to plug into to the external SHUTTER connector located on the rear of the BLAZE camera (see Figure 2-6 on page 24). Shutters that have been supplied by Teledyne Princeton Instruments will be equipped with the proper connector or an appropriate adapter cable.

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)

NOTE:

Many Teledyne Acton Research-series spectrometers are equipped with a LEMO connector. An adapter cable (P/N: 6050-0762) is available for use with them. Contact Teledyne Princeton Instruments for information about ordering this cable. Refer to Contact Information on page 170 for complete information.

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 BLAZE 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.

Appendix B: Outline Drawings

This appendix provides outlines drawing for the BLAZE Camera System.

Figure B-1: Outline Drawing: BLAZE Camera

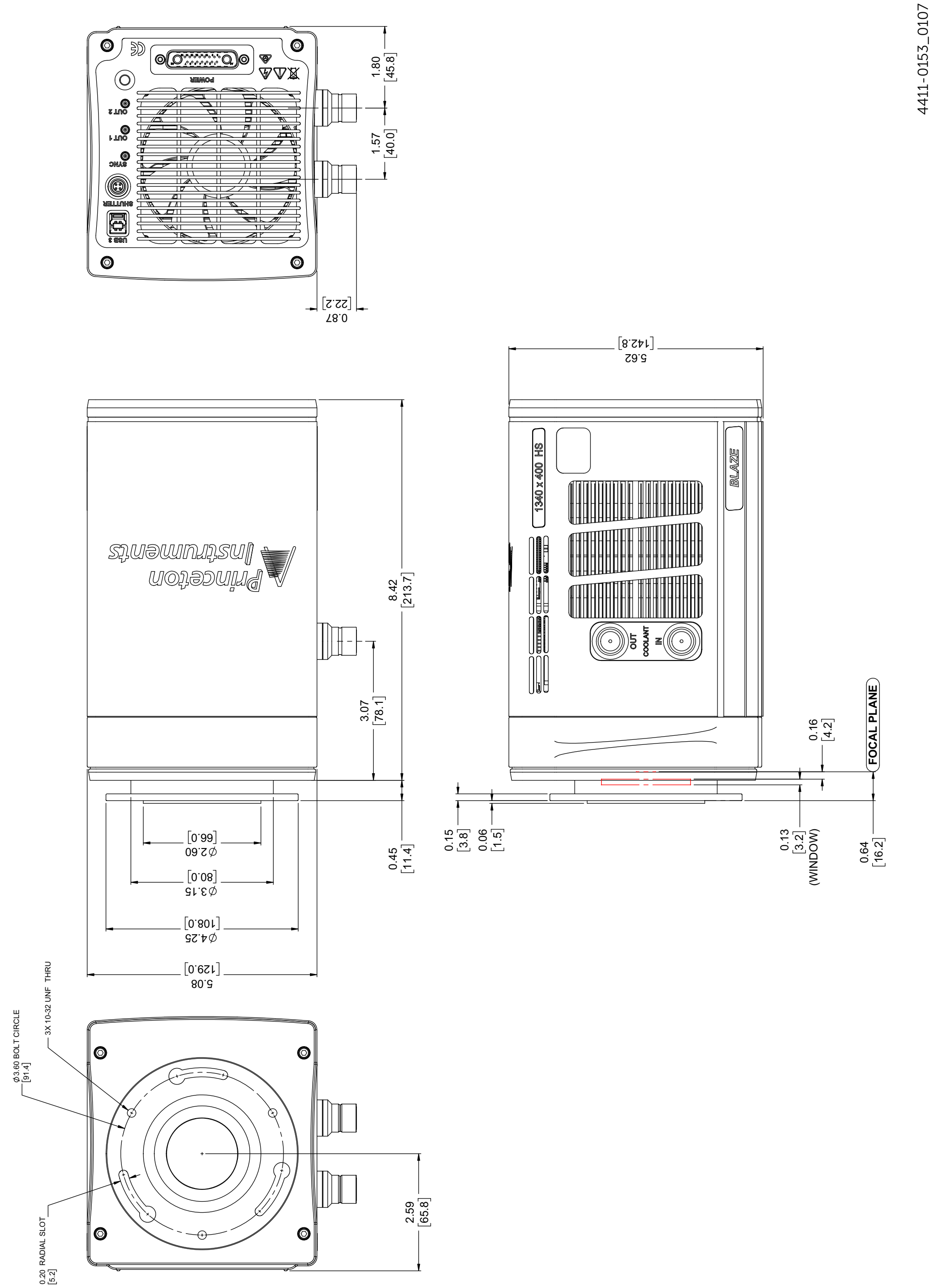
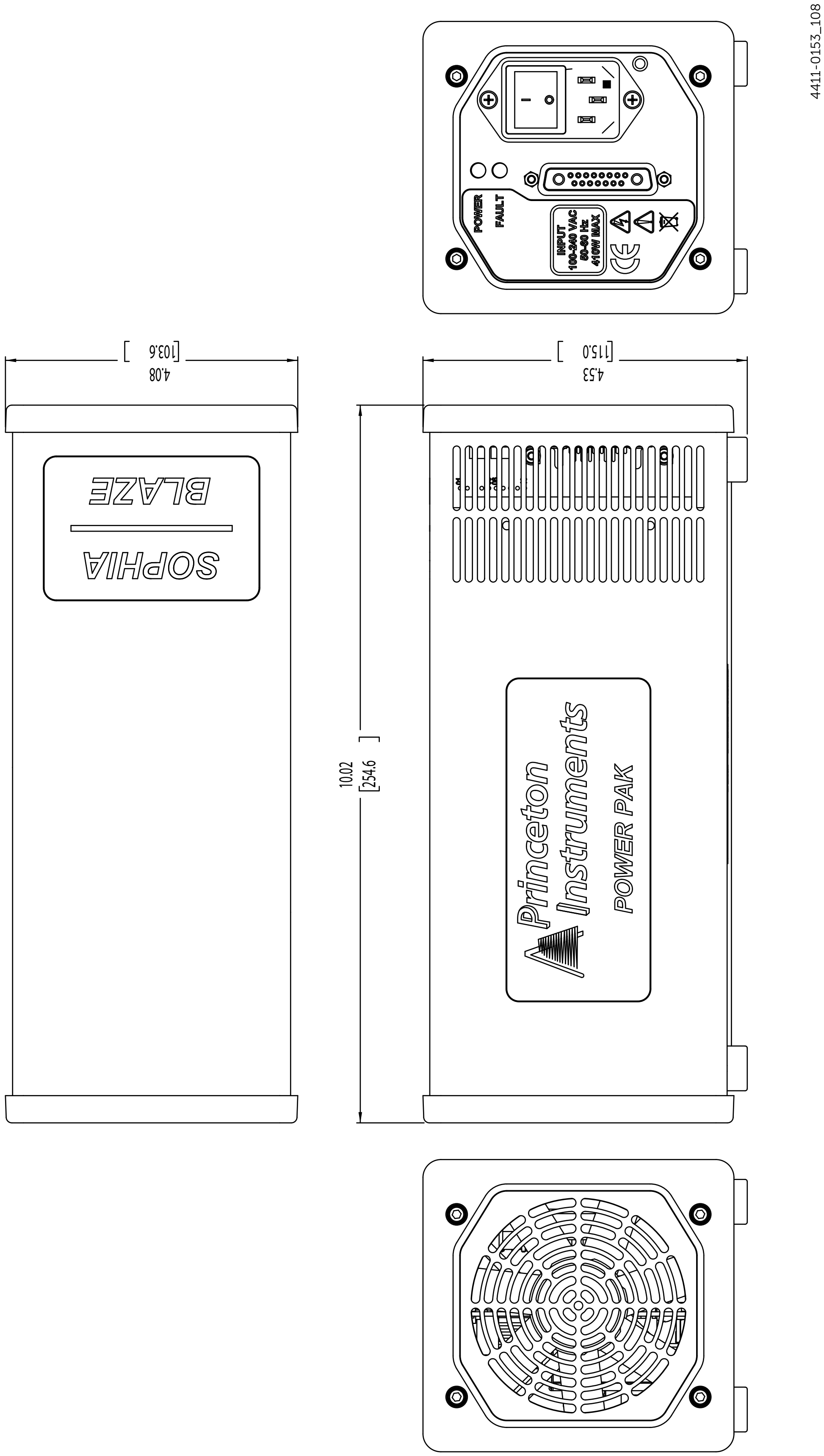


Figure B-2: Outline Drawing: BLAZE Power Supply



Appendix C: Drain Coolant from BLAZE

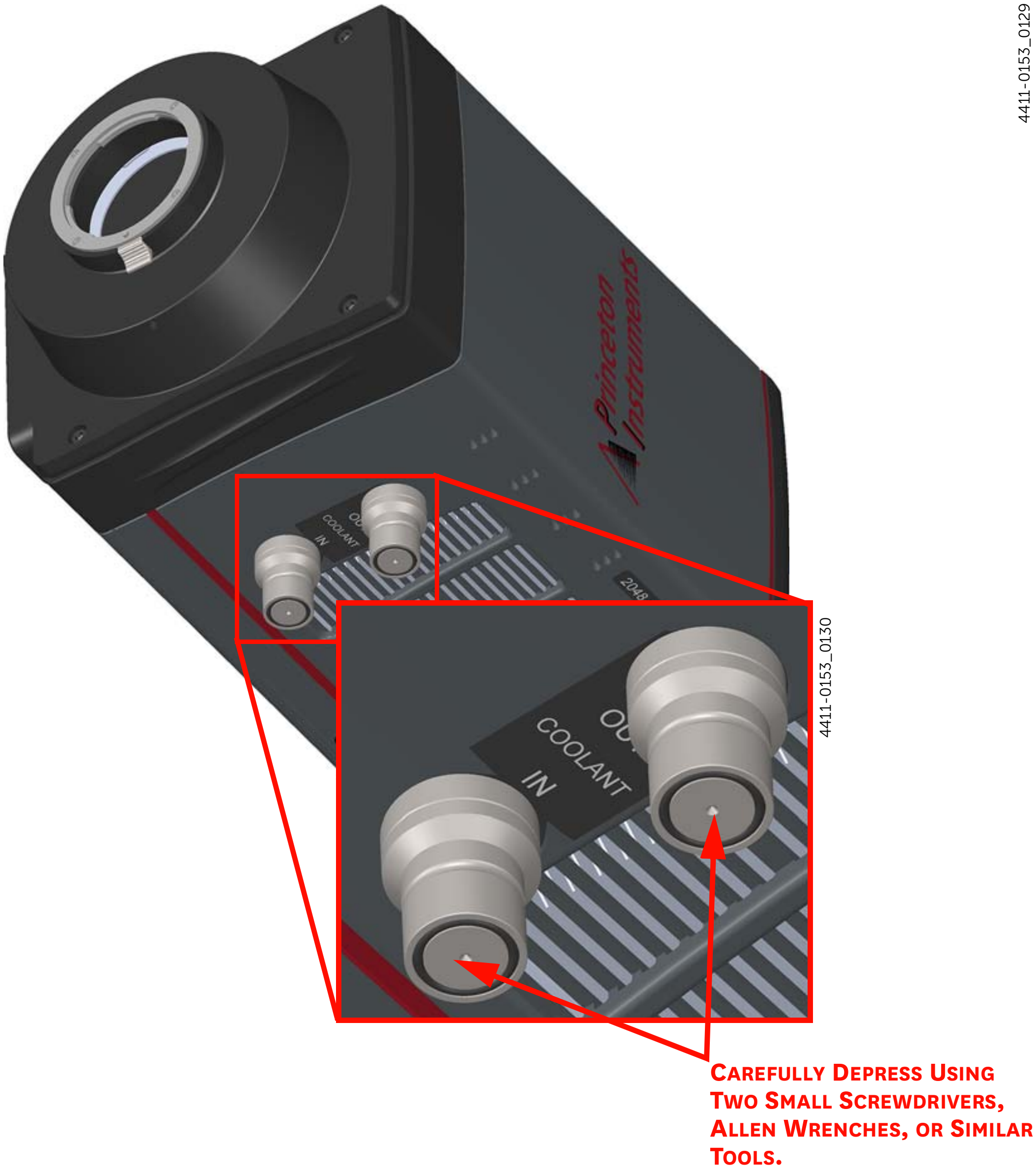
This appendix provides information necessary to safely drain coolant from within the BLAZE camera body.

1. Place BLAZE 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 C-1.

Figure C-1: Positioning BLAZE to Drain Coolant

2. Using two small screwdrivers, Allen wrenches, or similar tools, carefully depress the center piston on each coolant fitting simultaneously. See Figure C-2

Figure C-2: Depressing Coolant Fittings' Center Pistons



This will allow the coolant to drain out of the BLAZE and into the collection bucket.

NOTE:

It is not necessary to drain every drop of coolant out of the BLAZE, 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 BLAZE and/or surrounding areas.
5. If available, install rubber fitting covers onto the coolant fittings prior to shipping or storing the BLAZE.
6. Dispose of drained coolant according to local standards/requirements.

Appendix D: Custom Modes

Custom Sensor and Custom Timing are standard with LightField, although both are sensor and readout mode-dependent. These modes enable data acquisition at the fastest possible rates for the camera. Custom Sensor allows the apparent size of the CCD array to be reduced, while Custom Timing allows a faster vertical shift time to be selected.

D.1 Custom Sensor

In addition to Binning and ROI (previously discussed in the manual), the Custom Sensor feature can be used to reduce Readout Time.

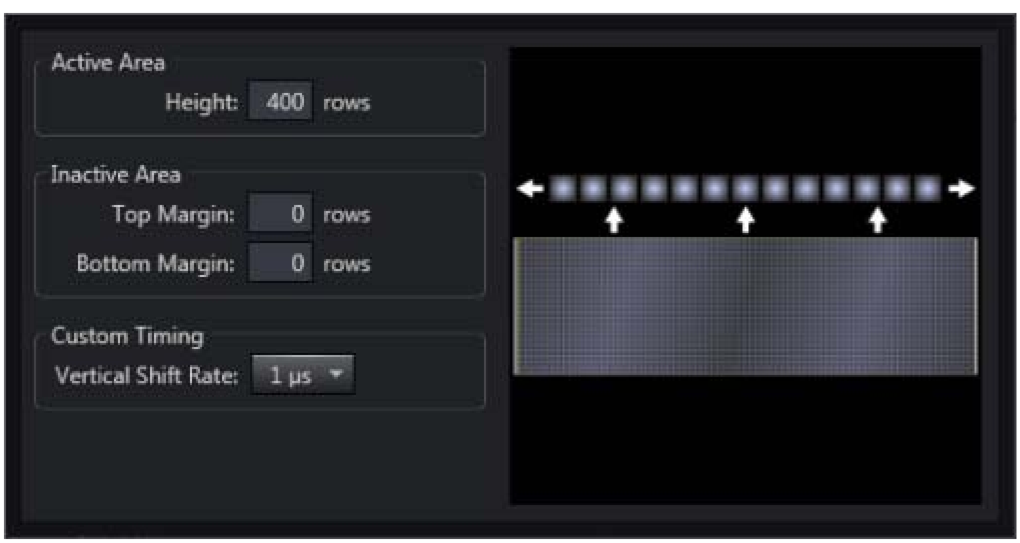
NOTE:

Teledyne Princeton Instruments does not encourage users to change these parameter settings. For most applications, the default settings will give the best results. There are limitations to this technique, such as requiring the careful positioning of the light on the active section of the CCD and darkness on the rest of it.

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 D-1, is accessed by opening the Sensor expander and clicking on the Custom Sensor button.

Figure D-1: Custom Sensor Pane



By changing the values in the Active fields, the 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.

With a high performance imaging spectrometer, such as Teledyne Princeton Instruments' IsoPlane family, this can be done by masking at the input of the spectrometer. This has the advantage of preventing the need to add masking inside the camera. Older imaging spectrometers can be used this way, but the results will not be as good as with an IsoPlane.

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

> **NOTE:**
> The Clean Serial Register function only appears in the Sensor Cleaning pane when the Inactive Area Top Margin is 0 rows. Deselect the check box to deactivate the serial register cleaning.

If using Custom Sensor to achieve a higher frame rate, Teledyne Princeton Instruments recommends that two outputs be used. Therefore, the Custom Sensor parameters should be configured so that the virtual CCD is symmetrical about the centerline so both outputs can be used.

D.1.1 Custom Timing

> **NOTE:**
> Custom Timing is standard within LightField for full frame CCD cameras.

Custom Timing 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 D-2.

Figure D-2: Custom Timing

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Appendix E: Troubleshooting

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

The BLAZE 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 E-1 for additional information.

Table E-1: Fault LED Error Codes

Flashes	Error/Fault	Refer to...
1	TEC Overcurrent	
3	Shutter Power Supply Overcurrent	Shutter Power Supply Overcurrent on page 162
Solid	Connection Failure or Logic Power Supply Overcurrent	Connection Failure or Logic Power Supply Overcurrent on page 158

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 170 for complete information.

Additional troubleshooting guidelines for issues that may occur while working with a BLAZE system are provided. Refer to Table E-2 for specific troubleshooting sections.

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

Error/Fault	Refer to...
Power Supply Switch in On Position, But Power LED Extinguished	page 158
Overexposed CCD	page 159
Baseline Signal Suddenly Changes	page 159
Camera Stops Working	page 159
Temperature Lock Cannot be Achieved or Maintained	page 160
Camera Loses Temperature Lock	page 161
Gradual Deterioration of Cooling Capability	page 161

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

E.1 General Camera Faults/Errors

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

E.1.1 Connection Failure or Logic Power Supply Overcurrent

This failure is indicated by the red FAULT LED on the rear of the BLAZE 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 170 for complete information.

E.1.2 Power Supply Switch in On Position, But Power LED Extinguished

If the power supply has been turned on (i.e., power switch is in the I position,) but the green POWER LED does not illuminate indicating the power supply is operational:

- Turn the power switch off (i.e., the 0 position);
- Wait approximately five seconds;
- Turn the power switch on (i.e., the I position)

If the green POWER LED still remains extinguished, the power supply must be returned to Teledyne Princeton Instruments for repair. Refer to Contact Information on page 170 for complete information.

E.1.3 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.

E.1.4 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 170 for complete information.

E.1.5 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 E-1, Fault LED Error Codes, on page 157 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 170 for complete information.

E.2 Cooling Faults/Errors

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

E.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 BLAZE can achieve. Return the temperature setpoint to −80°C, the default for BLAZE.

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

- Ambient temperature greater than +23°C. If the ambient temperature is greater than +25°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.
- If using liquid cooling, additional causes for a failure to achieve and/or maintain lock may include:
  - A hose is kinked. Unkink the hose.
  - Coolant level is low. Add coolant. Refer to Section E.2.4, External Coolant Circulator: Low Coolant (Air in the Hoses), on page 161.
  - There may be air in the hoses. Add coolant. Refer to Section E.2.4, External Coolant Circulator: Low Coolant (Air in the Hoses), on page 161.
  - 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 170 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. BLAZE 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 170 for complete information.

E.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.

E.2.3 Gradual Deterioration of Cooling Capability

While unlikely with the BLAZE 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 170 for complete information.

E.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 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.

E.3 Shutter Faults/Errors

Each external shutter that is compatible with BLAZE has a Minimum Exposure Time (MET.) Refer to Table A-7, BLAZE External Shutter Specifications, on page 149 for specific values. 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.

NOTE:

Shutters are not covered by the warranty.

This section provides information about troubleshooting shutter-related issues.

E.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.

E.3.1.1 BLAZE HR Systems

BLAZE: HR (high-rho CCD system) can accumulate many cosmic ray events in longer exposures. Cosmic ray events typically look like short streaks, short curved tracks or blotches, or a combination thereof, particularly for long exposures. These indications have nothing to do with the shutter.

E.3.2 Shutter Power Supply Overcurrent

When the red FAULT LED on the rear of the BLAZE 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, there may be a fault in the either external shutter or its wiring.
  Examine the shutter's wiring as well as the external shutter itself (if user-supplied) before contacting customer service.
  Refer to Contact Information on page 170 for complete information.

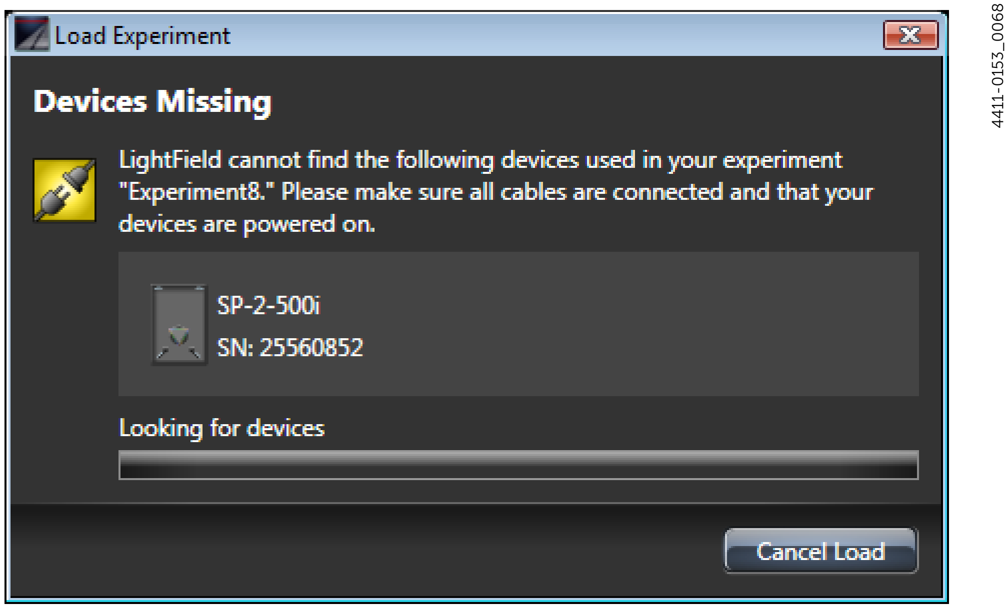
E.4 LightField Faults/Errors

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

E.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 E-1 is displayed while LightField continues searching for the missing device.

Figure E-1: Devices Missing Dialog



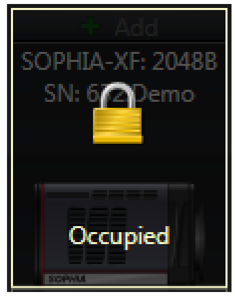
Perform the following steps to try to resolve this fault:

- 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.

E.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 E-2.

Figure E-2: Typical LightField Occupied Device



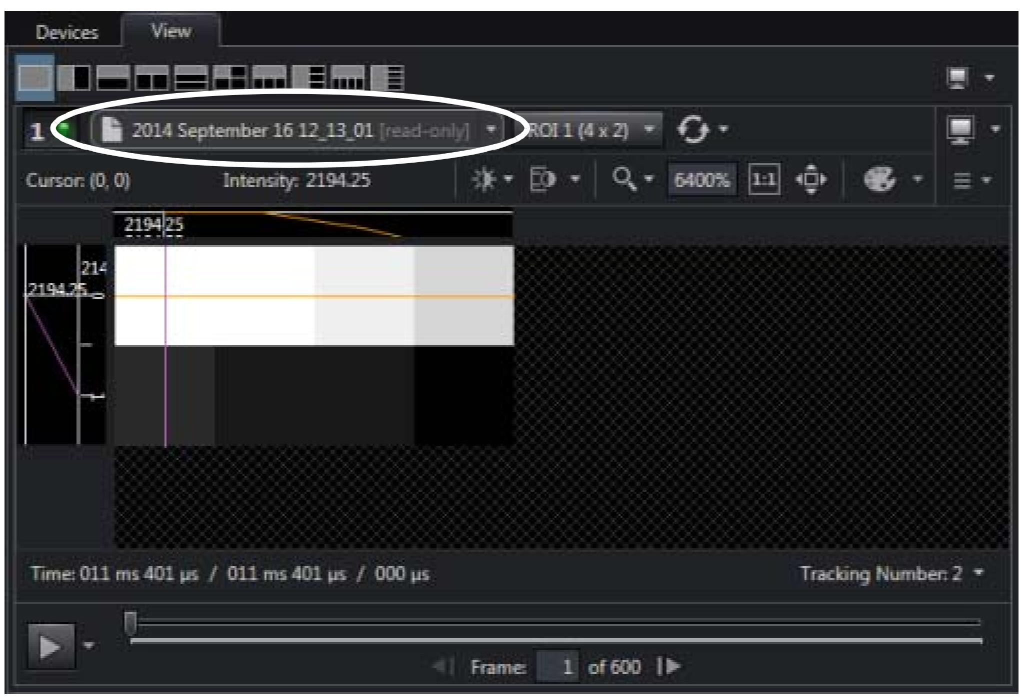
4411-0153_0071

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.

E.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 E-3.

Figure E-3: Typical Acquisition Display

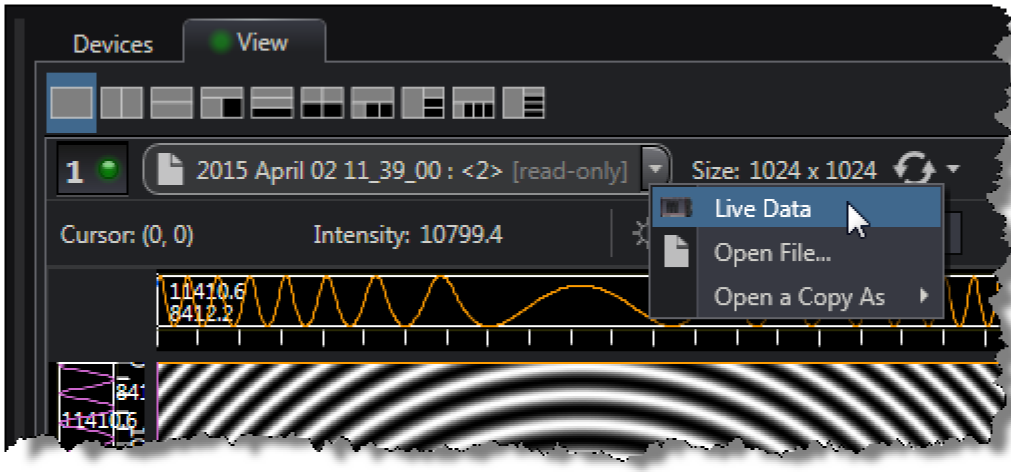


4411-0153_0069

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 E-4.

Figure E-4: Data Viewer Menu



4411-0153_0070

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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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www.princetoninstruments.com

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