Cascade
Photometrics

PHOTOMETRICS®
a division of Roper Scientific, Inc.

User Manual for Cascade® Systems

**Model 650, Model 1K, Model 512F, Model 512B,
Model 128+, and Model 128**

LIMITED WARRANTY

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

Basic Limited One (1) Year Warranty

Photometrics 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, Photometrics will repair the product or, at its sole option, repair or replace any defective part without charge to you. You must deliver the entire product to the Photometrics factory or, at our option, to a factory-authorized service center. You are responsible for the shipping costs to return the product. International customers should contact their local Photometrics authorized representative/distributor for repair information and assistance, or visit our technical support page at www.photomet.com.

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

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

Normal Wear Item Disclaimer

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

Sealed Chamber Integrity Limited 24 Month Warranty

Photometrics warrants the sealed chamber integrity of all our products for a period of twenty-four (24) months after shipment. If, at anytime within twenty-four (24) 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 24 Month Warranty

Photometrics warrants the vacuum integrity of all our products for a period of up to twenty-four (24) 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 twenty-four (24) 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.

Software Limited Warranty

Photometrics 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. Photometrics does not warrant that the function of the software will meet your requirements or that operation will be uninterrupted or error free. You assume responsibility for selecting the software to achieve your intended results and for the use and results obtained from the software. In addition, during the one (1) year limited warranty. The original purchaser is entitled to receive free version upgrades. Version upgrades supplied free of charge will be in the form of a download from the Internet. Those customers who do not have access to the Internet may obtain the version upgrades on a CD-ROM from our factory for an incidental shipping and handling charge. *See Item 12 in the following section of this warranty ("Your Responsibility") 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 Photometrics 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 Photometrics technical support staff or our authorized service representative. *See Item 12 in the following section of this warranty ("Your Responsibility") 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 Photometrics.

2. You must notify the Photometrics 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 Photometrics factory or, at our option, an authorized service center.

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

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

6. Unless specified in the original purchase agreement, Photometrics 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;

   - been damaged as a result of misuse, improper installation, faulty or inadequate maintenance or failure to follow instructions furnished by us;

   - had serial numbers removed, altered, defaced, or rendered illegible;

   - been subjected to improper or unauthorized repair; or

   - been damaged due to fire, flood, radiation, or other "acts of God" or other contingencies beyond the control of Photometrics.

8. After the warranty period has expired, you may contact the Photometrics factory or a Photometrics-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 Photometrics' 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 Photometrics factory of purchase, contact your authorized Photometrics representative or reseller, or visit our technical support page at www.photomet.com.

Declaration of Conformity

Roper Scientific, Inc. declares on its sole responsibility that the equipment described in this document is in conformance with the requirements of the European Council Directives, listed below:

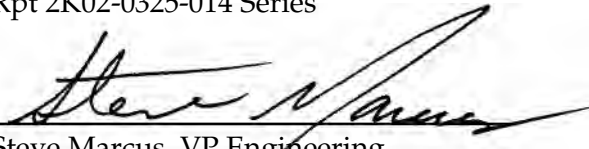|	
89/336/EEC	EMC Directive & Amendments
93/68/EEC	EMC Directive & Amendments
73/23/EEC	Product Safety with Amendments

on the application of the laws of Member States relating to Electromagnetic Compatibility & Product Safety.

This declaration is based upon compliance of the product to the following standards:

EN 55022, CISPR 22A	RF Emissions Control
EN 61000-3 series	Harmonics and Flicker Emissions
EN 55024	Immunity with Electromagnetic Disturbances
EN 60950	Product Safety

Product Description: Digital Camera
Models: Cascade 650 and Cascade 1K

Test Reports: Rpt 2K02-0325-014 Series

Responsible Person:
Steve Marcus, VP Engineering
Roper Scientific, Inc.
3440 E. Britannia Drive
Tucson, Arizona 85706

Manufacturer: Roper Scientific, Inc.

CE

Declaration of Conformity

Roper Scientific, Inc. declares on its sole responsibility that the equipment described in this document is in conformance with the requirements of the European Council Directives, listed below:

89/336/EEC	EMC Directive & Amendments
93/68/EEC	EMC Directive & Amendments
73/23/EEC	Product Safety with Amendments

on the application of the laws of Member States relating to Electromagnetic Compatibility & Product Safety.

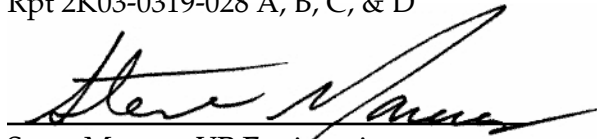This declaration is based upon compliance of the product to the following standards:

EN 55022, CISPR 22A	RF Emissions Control
EN 61000-3 series	Harmonics and Flicker Emissions
EN 55024	Immunity with Electromagnetic Disturbances
EN 60950	Product Safety

Product Description: Digital Camera
Models: Cascade 512F and Cascade 512B

Test Reports: Rpt 2K03-0319-028 A, B, C, & D

Responsible Person: _____
                     Steve Marcus, VP Engineering
                     Roper Scientific, Inc.
                     3440 E. Britannia Drive
                     Tucson, Arizona 85706

Manufacturer: Roper Scientific, Inc.   CE

Declaration of Conformity

Roper Scientific, Inc. declares on its sole responsibility that the equipment described in this document is in conformance with the requirements of the European Council Directives, listed below:

89/336/EEC	EMC Directive & Amendments
93/68/EEC	EMC Directive & Amendments
73/23/EEC	Product Safety with Amendments

on the application of the laws of Member States relating to Electromagnetic Compatibility & Product Safety.

This declaration is based upon compliance of the product to the following standards:

EN 55022, CISPR 22A	RF Emissions Control
EN 61000-3 series	Harmonics and Flicker Emissions
EN 55024	Immunity with Electromagnetic Disturbances
EN 60950	Product Safety

Product Description: Digital Camera
Models: Cascade 128+ and Cascade 128

Test Reports: Rpt 2K03-0319-028 A, B, C, & D; Rpt D0450029; Rpt D0450032; and Test G0480097

Responsible Person: _____
E. J. Pisa, V.P. of Engineering
Roper Scientific, Inc.
3440 E. Britannia Drive
Tucson, Arizona 85706

Manufacturer: Roper Scientific, Inc.   CE

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Chapter 1. Introduction

Description   The Photometrics® Cascade® line of cameras from Photometrics uses an advanced CCD technology called "impact ionization" to achieve charge multiplication gain above the read noise. As a result, the cameras offer unparalleled sensitivity even at high frame rates.

Cascade cameras are most suited for high speed and/or low-light level imaging applications such as single molecule fluorescence, ion imaging, and adaptive optics. With the traditional readout amplifier, Cascade: 512F and 512B can also be used for standard fluorescence and imaging applications requiring higher dynamic range.

Currently the Cascade line consists of the following camera models:

- Cascade:650
  - Uses a 653x492 Front-illuminated CCD with 7.4x7.4 µm pixels
  - Has one readout amplifier (charge multiplication gain).
- Cascade:1K
  - Uses a 1004x1002 Front-illuminated CCD with 8x8 µm pixels
  - Has one readout amplifier (charge multiplication gain).
- Cascade:512F
  - Uses a 512x512 Front-illuminated CCD with 16x16 µm pixels
  - Has two readout amplifiers – one that offers charge multiplication gain and another for traditional readout.
- Cascade:512B
  - Uses a 512x512 Back-illuminated CCD with 16x16 µm pixels
  - Has two readout amplifiers – one that offers charge multiplication gain and another for traditional readout.
- Cascade:128+
  - Uses a 128+ x128+ Back-illuminated CCD with 24x24 µm pixels
  - Has one charge multiplication gain readout port.
- Cascade:128
  - Uses a 128x128 Back-illuminated CCD with 24x24 µm pixels
  - Has one charge multiplication gain readout port.

Note: The 512F and 512B are also offered with a "multiplication only" readout amplifier. Check your camera configuration.

Note: Unless otherwise specified, the information in this manual applies to all Cascade models (the 650, the 1K, the 512F, the 512B, the 128+, and the 128).

Technology Introduction

The principal difference between a charge-multiplying CCD and a traditional CCD is the presence of an extended serial register in the new device (see *Figure* 1). Electrons are accelerated from pixel to pixel in the extended portion of the serial register (also referred to as a multiplication register) by applying higher-than-typical CCD clock voltages. This causes secondary electrons to be generated in the silicon by impact ionization. The degree of multiplication gain is controlled by increasing or decreasing the clock voltages for this register (gain is exponentially proportional to

the voltage). Although the probability of generating secondary electrons is fairly low (typically 0.01 per stage), over the large number of stages of a typical multiplication register, the total gain can be quite high.

This technology combines the ease of use and robustness of a traditional CCD with the gain capabilities of an intensified CCD in a single device. The combination of this technology with frame-transfer readout makes the Cascade cameras excellent choices for experiments where fast framing and low light sensitivity are required.
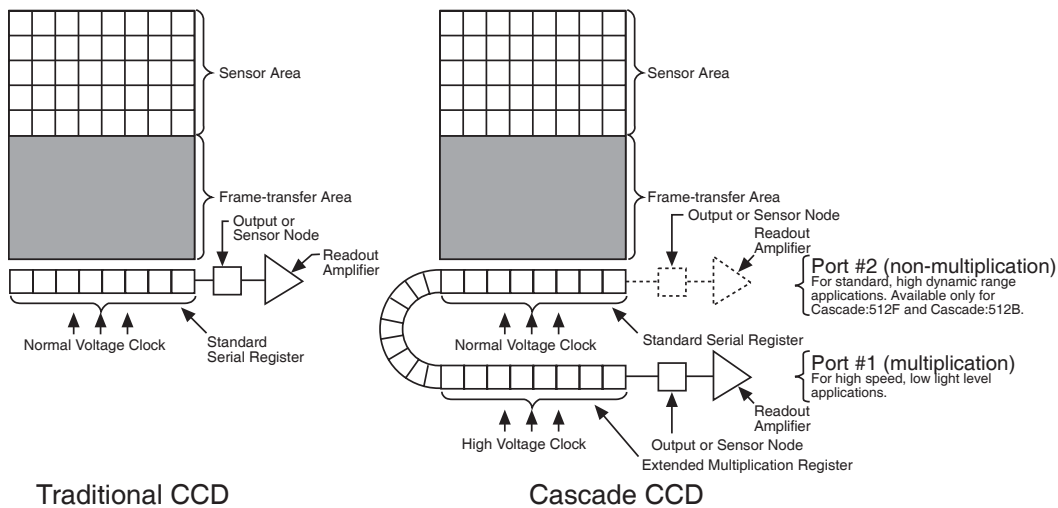
Traditional CCD labels:
- Sensor Area
- Frame-transfer Area
- Output or Sensor Node
- Readout Amplifier
- Normal Voltage Clock
- Standard Serial Register

Cascade CCD labels:
- Sensor Area
- Frame-transfer Area
- Output or Sensor Node
- Readout Amplifier
- Port #2 (non-multiplication) — For standard, high dynamic range applications. Available only for Cascade:512F and Cascade:512B.
- Normal Voltage Clock
- Standard Serial Register
- Port #1 (multiplication) — For high speed, low light level applications.
- Readout Amplifier
- High Voltage Clock
- Output or Sensor Node
- Extended Multiplication Register

Traditional CCD   **Cascade CCD**

Figure 1. Comparison of Traditional CCD and Cascade CCD Array Structures

Cascade:512F and 512B also offer a non-multiplication readout similar to the one available in traditional CCD cameras. This makes these more versatile cameras that can be used for standard imaging applications requiring higher dynamic range.

System Components

In addition to the components shown below, the Cascade package also includes PVCAM® drivers and QED Capture™ software.

Camera (with Test Lens) and DATA Cable

PCI Card   *Power Supply with Power Cord*

About This Manual

The *Cascade User Manual* is divided into five chapters. It is suggested that you read the entire manual before operating the camera in order to ensure proper use. The chapters that follow this introduction are briefly described below.

Note: The information in these chapters applies to the Cascade:650, the Cascade:1K, the Cascade:512F, the Cascade:512B, the Cascade:128+ , and the Cascade:128 models unless otherwise specified.

- **System Installation —** Instructions for connecting your Cascade camera to your computer via the Cascade PCI card.
- **Operating Features —** Discusses Cascade features such as on-chip multiplication gain, readout, and trigger modes. Provides additional information on dual-readout mode feature available on Cascade: 512F and Cascade:512B.
- **Troubleshooting —** Provides answers to camera system problems.
- **Basic Specifications —** Provides specifications for Cascade system components.

Precautions

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

- If you are using high-voltage equipment (such as an arc lamp) with your camera system, be sure to turn the camera power *on last* and power the camera *off first.*
- Never connect or disconnect any cable while the camera system is powered on.
- Although you should switch off the *camera's* power before disconnecting any camera system cable, you do *not* need to power off your computer to detach the cables.
- Use caution when triggering high-current switching devices (such as an arc lamp) near your system. 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.
- Always leave one inch of space around the camera's external cooling fins for airflow.
- Never open the camera. There are no user-serviceable parts inside the Cascade camera. Opening the camera voids the warranty.
- Use only the PCI card, cables, and power supply designated for this camera system. Using non-Cascade cables, PCI cards, or power supplies may result in permanent damage to your system.
- Do not use a C-mount lens that has optics that extend behind the lens flange.

Environmental Requirements

The Cascade camera system should be operated in a clean, dry environment.

The camera system's ambient operating temperature is 0°C to 30°C with 80% relative humidity, noncondensing.

Storage Requirements

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

Microscopes, Lenses, and Tripods

The camera has a standard threaded video mount and can be mounted to any microscope that accepts a standard C-mount adapter. The camera also allows you to install any lens that is compatible with a standard threaded video mount as long as its optics do not extend behind the flange of the lens. The Cascade camera can be mounted to a tripod using the tripod mounting attachment located on the bottom of the camera. See *Additional Measurements* on page 34 for more information.

The Cascade C-mount adapter is designed so it can be screwed in or out to change the focal depth. Once the focal depth as been changed, the adapter is secured by two setscrews. See *Adjusting the C-Mount Adapter* on page 10 for more information.

Note: In microscopy applications, a 0.6x C-mount camera coupler is recommended for a Cascade:650 to achieve proper field of view.

Repairs

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

Note: Do not open the camera. Opening the Cascade camera voids the warranty.

Cleaning

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

Photometrics Customer Service

If you have any questions about your camera system, contact Photometrics Customer Service. When you call, please have your Roper Scientific job number or equipment serial numbers available.

- Tel: 800.874.9789/ 520.889.9933 between 8:00 am and 5:00 pm MST
- Fax: 520.295.0299
- E-mail: cservice@photomet.com
- Mail: Photometrics
           3440 East Britannia Drive
           Tucson, Arizona 85706

In Europe, you can reach Customer Service at:

BENELUX
- Tel: 31.347.324989
- Fax: 31.347.324979
- E-mail: mailto@roperscientific.com
- Mail: Roper Scientific, BV
           Ir. D.S. Tuijnmanweg 10
           4131 PN VIANEN, Netherlands

FRANCE
- Tel: 33.160.86.03.65
- Fax: 33.160.86.07.09
- E-mail: princeton.instruments@wanadoo.fr
- Mail: Roper Scientific, SARL
           Z.I. Petite Montagne Sud
           4, rue de l'Oisans - C.E. 1702
           91017 Evry Cedex, France

GERMANY
- Tel: 49.89.660.779.3
- Fax: 49.89.660.779.50
- E-mail: mail@roperscientific.de
- Mail: Roper Scientific, GmbH
           Rosenheimer Landstr. 87
           D-85521 Ottobrunn, Germany

In Japan, you can reach Customer Service at:
- Tel: 81.43.274.8022
- Fax: 81.43.274.8023
- E-mail: sales@roper.co.jp
- Mail: Nipon Roper, K.K.
           D-10E 1-3 Nakase,
           Mihama-ku, Chiba-shi
           Japan 261-8501

General product information and answers to some customer service questions can be found on our website: http://www.photomet.com

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Chapter 2. System Installation

Introduction

Your Cascade camera system has the following hardware components:

- PCI card
- Camera and Data cable
- Power supply with Power cord.

Cascade system components are linked by the data cable and controlled by your host computer system. All of these hardware components should be included with your shipment. Refer to the information and figures in *System Components* on page 2.

The CCD you selected is installed in your camera.

Keep all the original packing materials so you can safely ship the Cascade system to another location or return it for service if necessary.

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

Software Compatibility Requirements

The Cascade package includes the PVCAM drivers and the QED Capture software program designed for use with your Cascade camera.

All other imaging software must also be PVCAM-compatible. For full access to Cascade hardware functions, the current version of PVCAM must be used.

Host Computer Requirements

The host computer (PC) for your Cascade camera must have the following:

- Windows® 2000, or Windows® XP operating system
- 1 GHz Pentium® 4 (or greater)
- 256 MB RAM (or greater)
- CD-ROM drive
- At least one unused PCI card slot
- 16-bit color display (or greater)

Note: The above requirements are the minimum for operating a Cascade camera. A faster computer (Pentium 4 or greater) with larger memory (RAM) will greatly enhance the software performance during live mode operations.

If you are a Mac® user, the host computer for your Cascade camera must have the following:

- Macintosh® OS X operating system

- G4/G5 computer

- 256 MB RAM (or greater)

- CD-ROM drive

- At least one unused PCI or PCI-X card slot

- Video adapter that supports 24-bit color (millions of colors)

Multiple Cameras

PVCAM supports multiple open cameras. In order to use this function, it must also be supported by your imaging software.

If your imaging software supports multiple cameras, there must be a separate PCI card for each camera.

Software Installation

An Installation Guide appropriate to your system is included as an insert in the CD-ROM case. This guide provides step-by-step instructions for installing the camera interface software and the application software for Windows-based computers. Additional instructions are included for installing a PCI card in your computer and capturing images.

The Photometrics CD-ROM contains the following files.

- **Linux directory —** this directory contains the files for installing on a Linux PC.

- **MacOS directory —** this directory contains the files required for installing on a Macintosh computer.

- **Manuals directory —** this directory contains user manuals in PDF format.

- **Win OS directory —** this directory contains the files for installing on a Windows PC.

Installing the PCI Card

You will be using a Cascade PCI card to allow the camera to communicate with your computer.

Before installing the PCI card, refer to the Readme text files on the CD-ROM and to the Software Installation insert. The insert instructions will step you through the PCI card installation.

After installing the PCI card, continue to *Connecting Your Cascade Camera*.

Connecting Your Cascade Camera

The following connectors are located on the back of the Cascade camera:

- *DATA connector:* 20-pin, high-density connector for data transfer.

- *POWER connector:* 5-pin, LEMO connector for camera power (see *POWER Connector Pinout* on page 36 for details).

- *I/O connector:* DB26, high-density connector for input/output control signals (see *I/O Connector Pinout* on page 37 for details).

- *Power switch:* Turns the camera on and off (| =on, 0=off).

To connect your Cascade camera:

1. Connect either end of the DATA cable to the Cascade PCI card that you have installed in the host computer. The DATA cable (shown below) connects your Cascade camera to the Cascade PCI card. This cable is identifiable by its 20-pin connectors. It is designed to serve as a conduit for data.

2. Connect the other end of the DATA cable to the DATA connector located on the back of the camera (shown below).

3. Verify that the power switch on the back of the camera is in the off position (| =on, 0=off).

4. Connect the power supply to the POWER connector on the back of the camera.

5. Plug the power cord into the power supply and then into a suitable wall outlet.

6. Switch on the camera (power switch on the back of camera).

Adjusting the C-Mount Adapter

The Cascade features an adjustable C-mount adapter that allows you to change the focal depth. Use a .050" hex key to adjust the adapter: loosen the two setscrews, rotate the ring to the desired height (the amount of travel possible depends on the camera model, see below), and tighten the screws to lock the adapter in place.
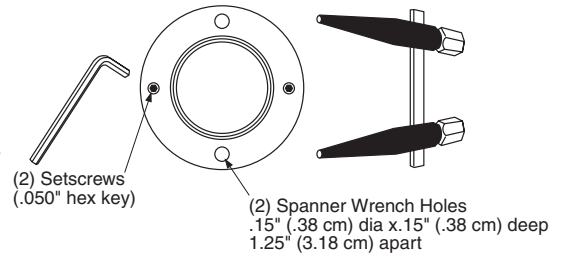

(2) Setscrews (.050" hex key)

(2) Spanner Wrench Holes .15" (.38 cm) dia x.15" (.38 cm) deep 1.25" (3.18 cm) apart

Figure 2. Adjustable C-Mount Adapter

Travel Distance:

Cascade:650, 1K, 512F, 512B, 128+, and 128 = .215"/.546 cm

Note: A spanner wrench can be used to rotate the adapter after the setscrews have been loosened. The spanner holes are .15" (.38 cm) dia. x .15" (.38 cm) deep and are spaced 1.25" (3.18 cm) apart. To lock the setscrews, the travel distance must be less than .215" (.54 cm).

Chapter 3. Operating Features

Common Features The features described in this section are identical in the Cascade:650, the Cascade:1K, Cascade:512F, the Cascade:512B, the Cascade:128, and the Cascade:128 cameras. Features that differ between the two models are described separately in the "Cascade:650 Features" and "Cascade:512F/512B/128+/128 Features" sections.

On-Chip Multiplication Gain As explained previously, the Cascade uses a unique CCD capable of multiplying the charge (electrons) generated in the pixels. When the multiplication is sufficiently high, it is possible to see extremely low-light events. The amount of multiplication is controlled by the voltage applied to multiplication register clocks. For convenience, a 12-bit DAC (digital-to-analog converter) is provided to adjust the multiplication factor in 4095 steps. The digital value is proportional to the clock voltages, which in turn has a complex relationship (approximated to an exponential) with the level of multiplication.

Offset (bias) CCD cameras are typically designed to produce a certain level of offset (also known as bias) when no light is present and the exposure time is set to zero (0). Typically, the offset (bias) is subtracted from the sample image for quantitative measurement. Since the offset can change based on several factors such as multiplication gain, speed, etc., it is recommended that a fresh offset (bias) image be taken with the same settings as the sample image and then be subtracted from the sample image.

Exposure-Readout Modes Cascade:650, Cascade:1K, Cascade:128+, Cascade 128, Cascade:512F, and Cascade:512B cameras use frame transfer CCDs and support Non-Overlap and Overlap exposure and readout modes. These modes are further described in the sections that follow.

Note: A frame transfer CCD has both a light-sensitive area (sensor area) and a storage area (frame transfer area). Since the image can be quickly transferred from the sensor area to the frame transfer area, there is no need for a mechanical shutter.

Non-Overlap Mode The Non-Overlap mode allows you to expose the array for the exposure time specified in the software and is similar in performance to a normal, full-frame device. The operational sequence for this mode is:

1. Clearing the CCD,

2. Exposing for the specified exposure time,

3. Shifting the image from the sensor area to the frame-transfer area, and

4. Reading out the CCD.

Steps 1-4 are repeated for each frame in a sequence. Steps 1 and 3, clearing the CCD and shifting the image, are usually very short and do not impact the frame rate.
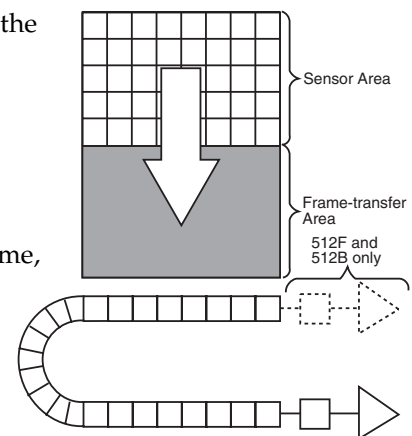
In PVCAM compatible software, this sequence is programmed by simply setting:

- clocking mode to "Frame transfer" and
- clearing mode to "Pre-exposure" with clear count of "1"(or more).

Figure 3 shows these settings on a software dialogue box.

Note: Since the software you are using may show the settings differently, you should refer to the software documentation for accurate information.
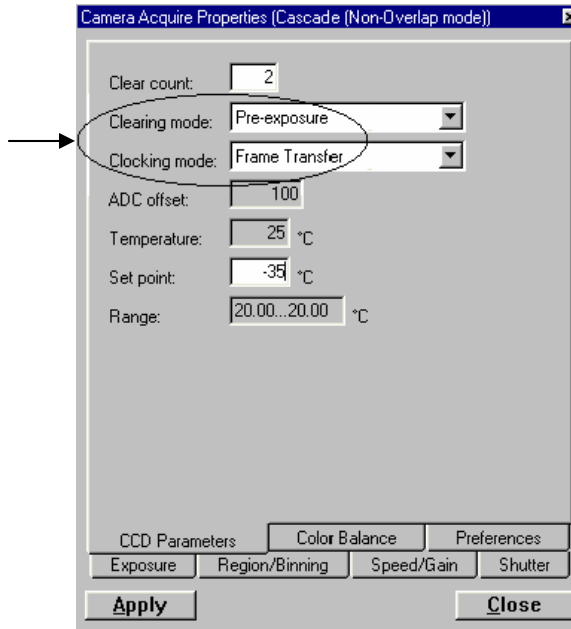

Figure 3. Required Settings for Non-Overlap Mode Operation

Example: Non-Overlap Mode

Operation in Non-Overlap mode is illustrated in the timing diagram below. In this example, the exposure time is 10 ms and the readout time is 34.8 ms. The total time to take 3 frames is 134.4 ms (3×10 ms + 3×34.8 ms), equivalent to a frame rate of 22.3 fps (3 frames ÷ 0.134 seconds).

Note: The exposure and readout times listed are for illustration purpose only. Actual values may vary. Refer to the product data sheet for the actual readout times.
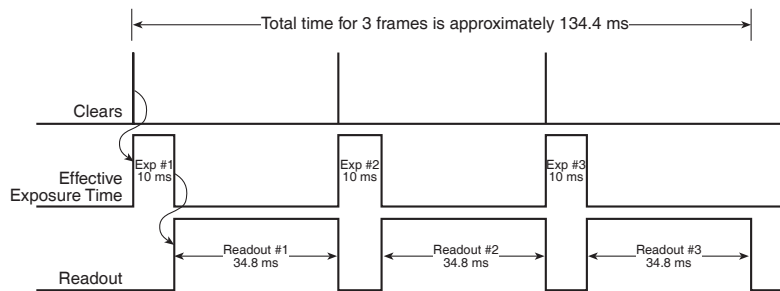
Figure 4. Timing Diagram for Non-Overlap Mode

Referring to *Figure 4*, it can be seen that exposure and readout are carried out in non-overlapped fashion. As a result, each frame in the sequence is precisely exposed for the time specified (i.e., 10 ms).

Overlap Mode (Simultaneous Exposure-Readout)

Overlap mode is extremely useful in applications requiring continuous imaging (100% duty cycle). Once a frame is exposed and transferred into the frame transfer area, the next exposure immediately starts and continues until the previous frame is read out or until the exposure time is finished, whichever is longer (so the minimum effective exposure time in this mode is the readout time). This mode of operation allows you to continuously image a specimen to obtain better kinetic information about a process.

Figure 5 shows the required PVCAM settings for overlap mode. Note that the clearing mode is set to "Pre-sequence" (as opposed to "Pre-exposure" in Non-Overlap mode).
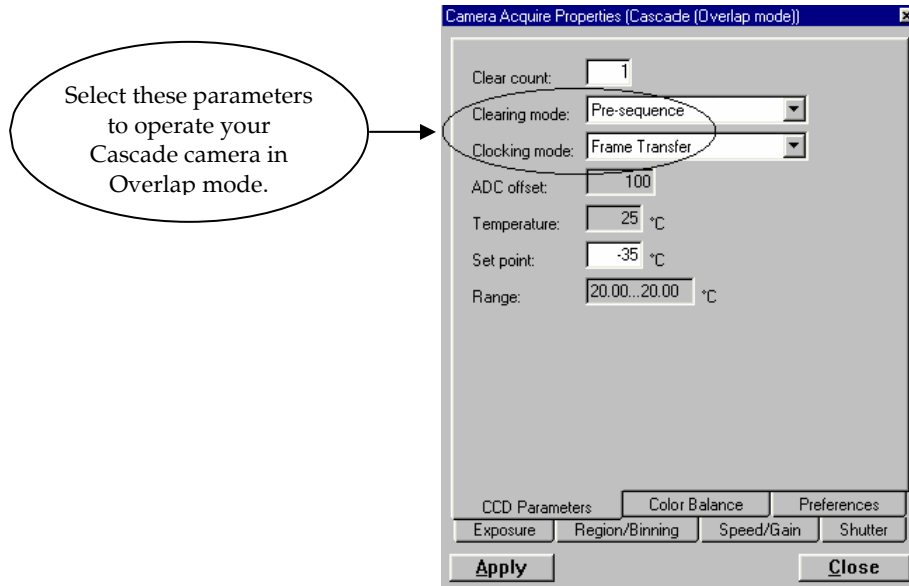
Figure 5. Required Settings for Overlap Mode Operation

Note: In Overlap mode, the minimum effective exposure time is the readout time.

The simultaneous exposure-readout mechanism is illustrated with two examples.

Example 1: Overlap Mode when Exposure Time < Readout Time

Consider a situation where full frame readout is 34.8 ms, the exposure time is 10 ms, and three frames are taken in overlap mode. The first frame is exposed precisely for the length of time entered into the software (10 ms) and all subsequent frames are exposed for the readout time. The total time to acquire 3 frames is then 114.4 ms (3×34.8 ms + 10 ms), equivalent to a frame rate of 26.2 fps (3 frames ÷ 0.114 seconds).

Note: Because the first frame is exposed for 10 ms and the others for 34.8 ms, the first frame may look less bright compared to all other frames.

In Overlap mode when exposure time < readout time, the total time (T_N) taken to capture N frames is given by:

$$T_N = (t_R \times N) + t_{exp}$$

Where

T_N = Total time taken to capture a sequence of N frames

t_R = readout time for one frame

N = total number of frames in a sequence

t_{exp} = exposure time
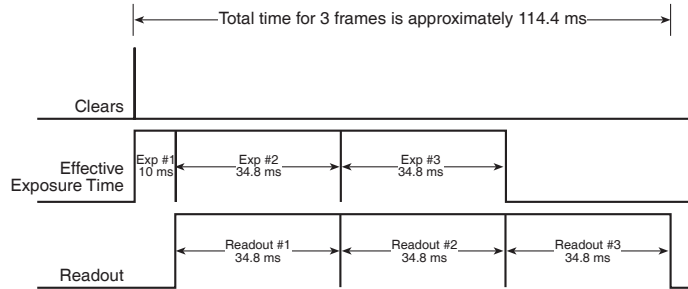
Figure 6. Timing Diagram for Overlap Mode when Exposure Time < Readout Time

Example 2: Overlap Mode when Exposure Time > Readout Time

If the exposure time is set to 50 ms with the readout time remaining at 34.8 ms, the time taken to acquire 3 frames will be 184.8 ms (3 × 50 ms + 34.8 ms), which is equivalent to a frame rate of 16.2 fps.

In Overlap mode when exposure time > readout time, the total time (T_N) taken to capture N frames is expressed as:

$$T_N = (t_{exp} \times N) + t_R$$

Where

T_N = Total time taken to capture a sequence of N frames

t_{exp} = exposure time

N = total number of frames in a sequence

t_R = readout time for one frame

From the timing diagram, you can see that because the exposure time is greater than the readout time, all frames are precisely exposed for the duration entered into the software and have similar intensities.
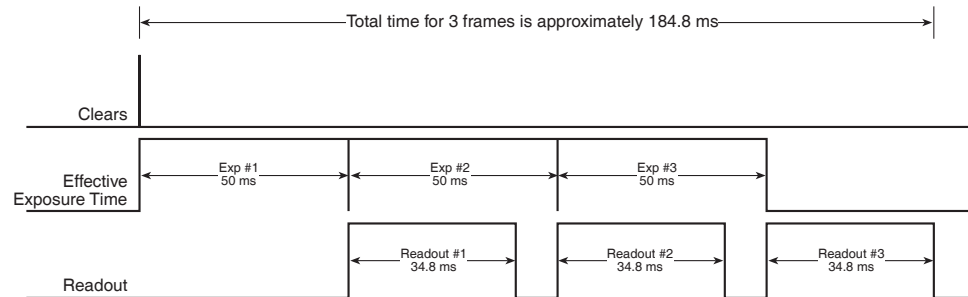
Figure 7. Timing Diagram for Overlap Mode when Exposure Time > Readout Time

Triggered Operation   Cascade:650, Cascade:1K, Cascade:128+, Cascade 128, Cascade:512F, and Cascade:512B cameras offer several methods of integration with external trigger sources, such as delay generators or laser pre-triggers. Each camera has a 26-pin, high-density I/O connector (pinout functions are described on page 37) on the back for trigger-in/out and various TTL input and output operations. A special cable is available from Roper Scientific to access primary signals such as "Trigger-in," "Trigger-invert," "Expose out," "Frame readout," and "Shutter out." In the default mode, the camera triggers on the rising edge of a TTL signal. To invert the triggering polarity, the "Trigger-invert" must be grounded, which can be done with a 50-ohm terminator. Cascade cameras support the trigger modes described in the next sections.

Trigger-first Mode   In this mode, the camera requires only one trigger to acquire a sequence of frames. The camera can operate in overlap or non-overlap mode depending on the settings explained in the previous section. Once the initial trigger is received, the camera ignores any further triggers until the entire exposure/readout sequence is completed (see *Figures 8 and 9, which show a three-frame sequence*).
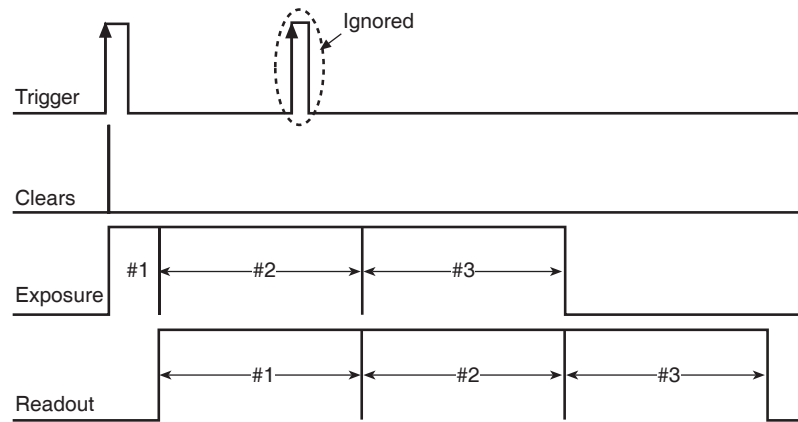
Figure 8. Trigger-First Mode Timing Diagram: Overlap Mode
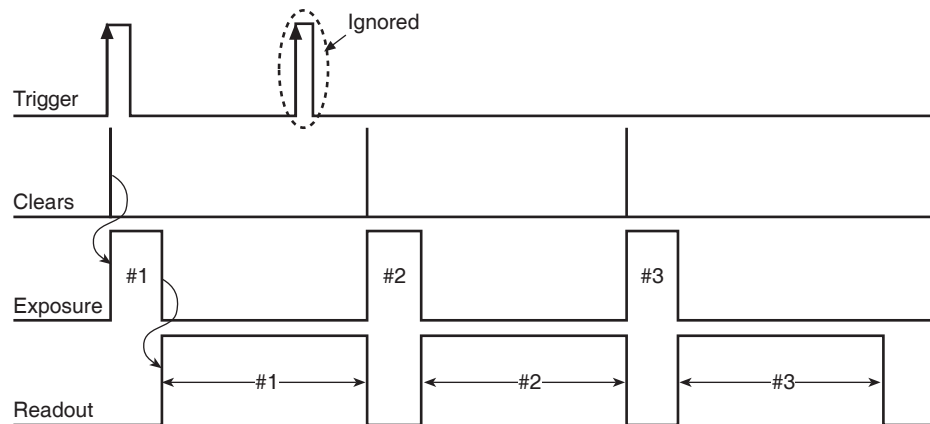
Figure 9. Trigger-First Mode Timing Diagram: Non-Overlap Mode

Strobe Mode   Strobe mode only operates in Non-Overlap mode. In Strobe mode, each frame in a sequence requires a trigger. Each frame is exposed for the length of time entered into the software and is then read out. If a trigger arrives during the exposure-readout of the previous frame, it is ignored (see *Figure 10*). For a sequence of one frame, strobe mode and trigger-first mode are the same. The shaded areas ▒ denote the idle time between exposures.
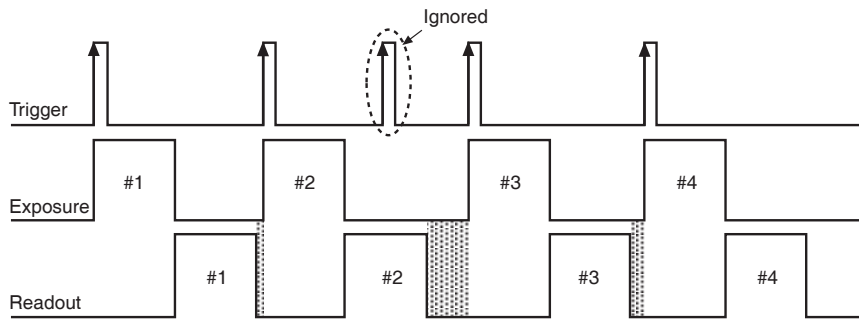
Figure 10. Strobe Mode Timing Diagram

Bulb Mode — Bulb mode only operates in Non-Overlap mode. In Bulb mode, exposure time for each frame is determined by the trigger pulse width. Exposure time entered into the software is ignored in this mode (see *Figure 11*). If a trigger arrives during the readout of the previous frame, it is ignored. The shaded areas ▦ denote the idle time between exposures.
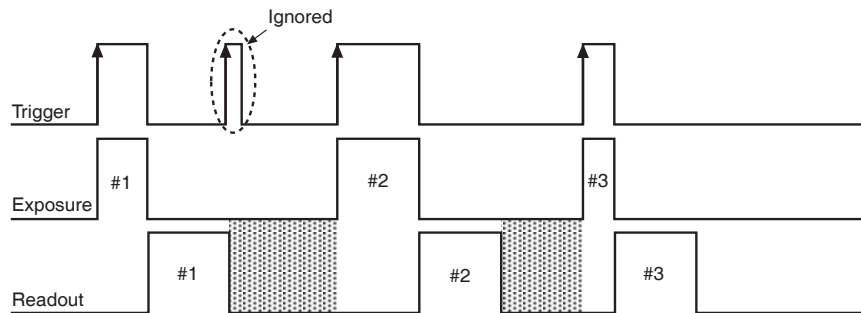

Figure 11. Bulb Mode Timing Diagram

Notes:

1. **When the clocking mode is "Alternate Frame Transfer", the camera can be operated in "Overlap" or "Non-Overlap" mode as explained previously.**

2. **When using the trigger-first, strobe, or bulb triggering mode, the camera cannot be operated in "Overlap" mode.**

AIMO / Non-AIMO — Camera users can choose to run the Cascade:128+ in either AIMO or non-AIMO mode. Each of these software-selectable modes of operation provides distinct performance characteristics:

- **AIMO** mode suppresses dark current, thereby optimizing camera sensitivity. Note, however, that this mode of operation will limit full-well capacity (typical single-pixel full well as high as 250 ke⁻, assuming neither vertical binning nor on-chip multiplication gain is utilized).

  Used as the default setting for Normal and Frame Transfer.

- **Non-AIMO** mode optimizes full-well capacity, thus making it possible to collect maximum signal. Although the typical single-pixel full well will be higher (up to 500 ke⁻), dark current will also be increased.

  Used as the default setting for Alternate Normal and Alternate Frame Transfer.

Note: The Cascade 128 does not utilize Non-AIMO mode of Operation

Cascade:650/1K Features

In absolute terms, the Cascade:650 and the Cascade:1K cameras have a greater than 200X multiplication factor. An approximate relationship between the DAC setting and charge multiplication factor for the Cascade:650 and the Cascade:1K is shown in the graph below.
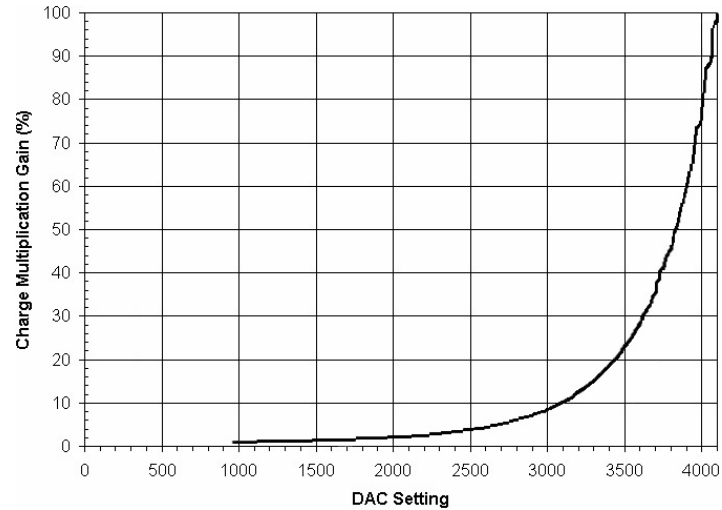
Figure 12. DAC Setting vs. Charge Multiplication Gain for Cascade:650 and Cascade:1K

As the software you are using may depict the multiplication gain differently, you should refer to the documentation that comes with it for accurate information. For example, a straightforward implementation will show a scale between 0 and 4095 with 0 being the minimum and 4095 representing the maximum multiplication gain. Because of the exponential nature of the gain, it may be possible to achieve even higher gains by increasing the voltage by only a small fraction at the higher end.

The charge multiplication also introduces additional noise, quantified by noise factor (F). Typically, F is measured between 1.0 and 1.4.

Note: As the on-chip multiplication introduces additional noise, it is recommended that the multiplication be used only as required. For more information, refer to the "On-Chip Multiplication Gain" technical note. This technical note can be accessed by going to the Photometrics web site at www.photomet.com, clicking on "Library", clicking on "Technical Notes", and selecting the title from the list of notes.

Conversion Gain

Apart from multiplication gain, which actually multiplies the number of electrons generated in each pixel, the Cascade:650 and the Cascade:1K also have three (3) conversion gains. Conversion gain simply quantifies how the resulting electrons are converted into ADU (Analog-to-Digital) units and displayed on the display screen.

Typical conversion gains for the readout port are listed in Table 1. Your camera is individually calibrated for these gains. So, please refer to the certificate of performance that accompanied your camera.

| Readout Speed (typical) | Cascade:650 is implemented with 10 MHz and 5 MHz digitization speeds (10 million and 5 million pixels per second, respectively). At 10 MHz, it gives approximately 25 full frames per second (fps), whereas 5 MHz operation offers better image quality. With either digitizer, increased frame rate can be achieved by choosing a sub-region. For more information, please refer to the product data sheets and to the table below. |

Cascade:650 is implemented with 10 MHz and 5 MHz digitization speeds (10 million and 5 million pixels per second, respectively). At 10 MHz, it gives approximately 25 full frames per second (fps), whereas 5 MHz operation offers better image quality. With either digitizer, increased frame rate can be achieved by choosing a sub-region. For more information, please refer to the product data sheets and to the table below.

Readout Amplifier	Readout Speeds	Conversion Gain (e$^-$/ADU)
Multiplication	5 MHz 10 MHz	#1: 2.2e$^-$/ADU #2: 1.1e$^-$/ADU #3: 0.6e$^-$/ADU

Table 1. Cascade:650 Readout Speeds and Typical Conversion Gains

Cascade:1K is implemented with a 10 MHz digitization speed and produces approximately nine full frames per second.

Readout Amplifier	Readout Speed	Conversion Gain (e$^-$/ADU)
Multiplication	10 MHz	#1: 2.0e$^-$/ADU #2: 1.0e$^-$/ADU #3: 0.5e$^-$/ADU

Table 2. Cascade:1K Readout Speed and Typical Conversion Gains

Both the Cascade:650 and the Cascade:1K use a frame-transfer CCD with a built-in storage (frame transfer) area, which makes simultaneous exposure and readout possible (Overlap mode) and which allows precise exposures to be set (Non-Overlap mode). These two readout modes are further explained in the "Exposure - Readout Modes", page 11.

Binning   Binning(combining pixels into one super pixel) allows you to increase the sensitivity and frame rate. On the other hand, binning reduces spatial resolution. The Cascade:1K allows binning of 1, 2, 3, 4, and 8 in the serial (horizontal) direction and arbitrary binning in the parallel direction. Due to CCD limitations, the Cascade:650 does not support hardware binning in the serial direction. However, some software packages allow "software" binning, which is performed after the data is read. Please refer to your software documentation.

Cascade:512F/ 512B/128+/128 Features

A 12-bit DAC is provided to control the multiplication gain of the Cascade: 512F, Cascade:512B, Cascade:128+, and Cascade:128 in 4096 steps. A DAC setting of zero (0) refers to a no-gain state where the camera behaves like a standard high speed CCD (with rather high read noise). Settings 1 to 4095 are mapped linearly to the internal serial clock voltages that vary the multiplication gain in a complex exponential fashion. Typically at a DAC setting of 4095, Cascade: 512F/512B/128+/128 can offer multiplication gain factor in the excess of 1000x. Even though the camera is capable of delivering large multiplication gain factors, multiplication gain should be used only as needed to preserve as much dynamic range as possible.

An approximate relationship between the DAC setting and charge multiplication factor for the Cascade:512F, 512B, 128+, and 128 is shown in the graph below.
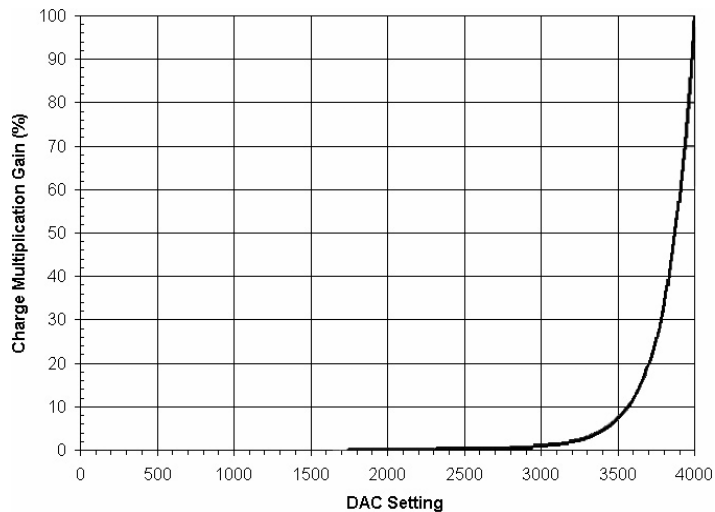
Figure 13. DAC Setting vs. Charge Multiplication Gain for Cascade:512F/512B/128+/128

Dual-Readout Port Operation

The Cascade:512F and 512B can be configured with software-selectable dual-readout amplifiers, also referred to as "ports", shown in *Figure 14*. The two amplifiers are listed below.

Port #1: On-chip Multiplication amplifier

Port #2: Traditional or non-multiplication amplifier
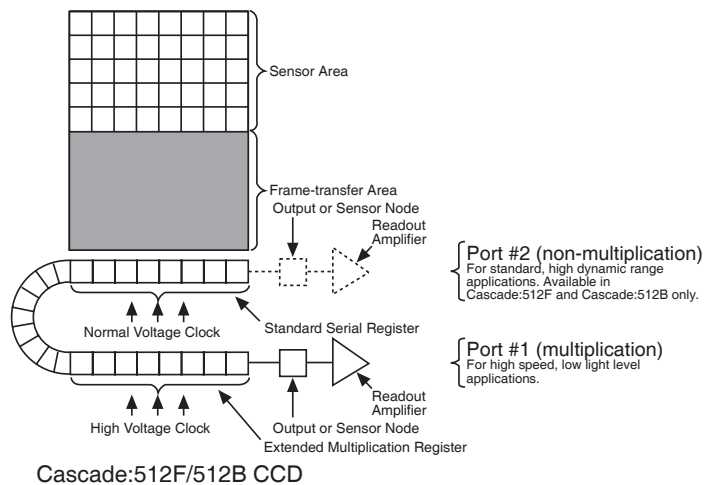
Figure 14. Cascade:512F and 512B CCD Array Structure

If your camera is configured with two readout amplifiers (ports), the software automatically allows port selection. An example of a software dialogue to select the ports is shown in *Figure 15*.
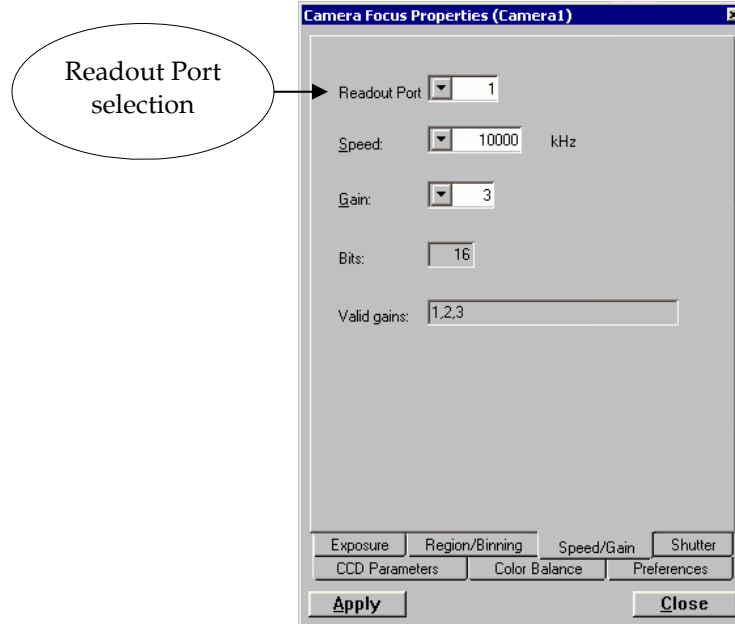
Figure 15. Software Selection of Readout Port

1. **On-Chip Multiplication Amplifier (Port #1):** Operation of multiplication gain in the Cascade:512F, 512B, 128+, and 128 is similar to that in Cascade:650. A setting of 0 (zero) results in unity gain and the subsequent DAC settings are exponentially related to the multiplication gain. Since the multiplication gain can be used to overcome the read noise of the fast amplifier, this mode is most useful in applications requiring low-light sensitivity at high frame rates (e.g., Single molecule fluorescence, ion imaging, etc.).

2. **Traditional or Non-Multiplication amplifier (Port #2):** When the camera is using this amplifier, electrons (signal) generated in pixels are clocked through the standard serial register. The amplifier is designed to take advantage of the dynamic range of the CCD and is most useful when the frame rate is not critical. (e.g., bright field, fixed cell fluorescence, etc.)

Note: Since the first pixel to be read out from Port #2 is at the bottom right (closest to the Port #2), the resulting image is a mirror image of the same image if it were read out of Port #1. Some software packages do a "horizontal-flip" in the software when Port #2 is selected to ensure the correct orientation for all ports. Please check your software documentation.

Conversion Gain

Apart from multiplication gain, which actually multiplies the number of electrons generated in each pixel, the Cascade:512F, 512B, 128+, and 128 also have three (3) conversion gains. Conversion gain simply quantifies how the resulting electrons are converted into ADU (Analog-to-Digital) units and displayed on the display screen.

Typical conversion gains for different ports are listed in Tables 2, 3, and 4. Your camera is individually calibrated for these gains. So, please refer to the certificate of performance that accompanied your camera.

Readout Speed (typical)

The Cascade:512F and 512B have two readout speeds available on each of the two ports as listed below:

Readout Amplifier (Port)	Readout Speeds	Conversion Gain (e⁻ /ADU)
Port #1 (Multiplication)	5 MHz 10 MHz	#1: 12e⁻ /ADU #2: 6e⁻ /ADU #3: 3e⁻ /ADU
Port #2 (Non-multiplication)	1 MHz 5 MHz	#1: 4e⁻ /ADU #2: 2e⁻ /ADU #3: 1e⁻ /ADU

Table 3. Cascade:512F and 512B Readout Speeds and Typical Conversion Gains

The Cascade:128+ has one readout speed available on its single (Multiplication) port as listed below:

Readout Amplifier	Readout Speed	Conversion Gain (e⁻ /ADU)
Multiplication	12 MHz	#1: 12e⁻ /ADU #2: 6e⁻ /ADU #3: 3e⁻ /ADU

Table 4. Cascade:128+ Readout Speed and Typical Conversion Gains

The Cascade:128 has one readout speed available on its single (Multiplication) port as listed below:

Readout Amplifier	Readout Speed	Conversion Gain (e⁻ /ADU)
Multiplication	10 MHz	#1: 12e⁻ /ADU #2: 6e⁻ /ADU #3: 3e⁻ /ADU

Table 5. Cascade:128 Readout Speed and Typical Conversion Gains

A slower readout speed can be used when better noise performance is needed at the expense of frame rate. On the other hand, increased frame readout rate can be achieved by one or more of the following

- higher readout speed,
- sub-region selection,
- binning.

For more information on frame rate, please refer to the product data sheet.

Binning Binning (combining pixels into one super pixel) allows you to increase the sensitivity and frame rate. On the other hand, binning reduces spatial resolution. The Cascade: 512F and 512B allow binning of 1, 2, 3, 4, 5, and 6 in the serial (horizontal) direction and arbitrary binning in the parallel (vertical) direction. The Cascade:128+ and the Cascade:128 allow binning of 1, 2, 3, and 4 in the serial (horizontal) direction and arbitrary binning in the parallel (vertical) direction.

Note: Due to the small array size in the Cascade:128+ and the Cascade:128, edge artifacts may be present at higher binning.

Application Examples: Cascade:512F and 512B

Example 1 *"I would like to obtain kinetic information (time-correlated) information of the single molecule fluorescence. My light level is fairly low and I want to optimize the frame rate of the camera."*

For this application, the "Multiplication" port (Port #1) should be selected and camera speed should be set to 10 MHz. In addition, the camera should be operated in "Overlap mode". This can be achieved by setting the camera to "frame transfer mode" with clearing mode "Pre-sequence" and number of clears "1" (refer to *Figure 5, page 13*). If possible, choose a sub-region (ROI) and/or binning to further increase the frame rate. Finally, on-chip multiplication gain can be used to boost the signal level and achieve a high signal-to-noise ratio.

Example 2 *"My application requires precise control of the exposure time (less than the readout time) and I want to operate the camera in the most sensitive mode possible."*

For better imaging characteristics, the "Multiplication" port (Port #1) is selected and camera speed must be set to 5 MHz. Use on-chip multiplication gain for increased sensitivity. To achieve an exposure time less than readout time, use Non-Overlap mode (as shown in *Figure 3, page 12*) and set the clearing mode to "Pre-exposure" and clear count to "2".

Example 3 *"I would like to image a bright target/sample (e.g., fluorescence or bright field) that is fixed. High resolution and high dynamic range are important."*

For imaging bright, non-moving samples, the "Non-multiplication" port (Port #2) offers the best performance in terms of dynamic range. Set the speed to 1 MHz (or 5 MHz, if higher speed is required) and conversion gain to #1 (this allows maximum full well of the CCD to be used). Reading out the full CCD (no-ROI or binning) gives best resolution possible. In addition, camera can be operated in overlap or non-overlap mode as explained before.

Summary Table 5, below, summarizes typical Cascade:512F and 512B settings for two types of applications and is provided as a setup aid. Actual settings will vary based on the exact nature of your experiment design.

Application	Readout Amplifier (Port)	Readout Speed	Multiplication Gain	Conversion Gain (e-/ADU)	Readout Mode
Kinetic samples (single molecule fluorescence or tracking)	Multiplication (Port #1)	10 MHz or 5 MHz	Use as required to obtain best signal-to-noise ratio (SNR). *Typical DAC values are around 3000.*	#2 (6 e-/ADU)	Overlap mode (Frame Transfer, Pre-Sequence)
Fixed samples (bright field)	Non-multiplication (Port #2)	1 MHz or 5 MHz	Not Applicable	#1 (4 e-/ADU)	Overlap or Non-overlap

Table 6. Application Type and Cascade:512F Setup Parameters

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Chapter 4. **Troubleshooting**

If you have any difficulty while troubleshooting, or do not see your camera system's symptoms listed here, contact Photometrics Customer Service.

System Does Not Boot Normally

If your operating system does not boot normally after you have installed a PCI card, try installing the new card in another open PCI slot. If this does not work:

1. *Turn off your computer* and remove the newly installed PCI card.

2. Turn your computer back on. If your system boots normally, there is probably an interrupt conflict between a previously installed expansion card and the PCI card that you are installing.

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

New Hardware Found Dialog Box Does Not Appear (Windows 2000/XP)

If the New Hardware Found dialog box does not appear after installing a new PCI card to your computer and booting Windows 2000/XP:

*   Check to make sure that the new PCI card is inserted in a PCI slot according to your computer manufacturer's instructions and that the Cascade system's HCK disc is in the host computer's CD drive.

*   It is possible that there is a conflict between the new PCI card and a previously installed expansion card. *With the computer's power turned off,* remove any previously installed expansion cards that your system does not need to function. (If you are unsure which cards can be safely removed, call Photometrics Customer Service.) Then turn your computer back on and boot Windows 2000/XP again.

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

Images Not Displayed

If no images appear:

*   Confirm that the switch on the camera is set to "|".

*   Confirm that the correct Cascade camera is selected in your imaging software application.

*   Power off the camera and the host computer and check all system connections (particularly the DATA and power cables). Restart.

*   Confirm that operating system is set for at least 64k colors (16 bits).

*   Confirm that the camera is operational by taking an image with a standard C-mount lens attached to your Cascade. Using normal room lighting, place the camera on a table about 3 meters away from an object and acquire an image.

If the problem persists, contact Photometrics Customer Service.

Camera Running Too Warm

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

Unlike other Cascade models, the Cascade:128 features a fanless design. Therefore, the cooling performance afforded by the Cascade:128 is highly sensitive to the camera's orientation and environment. Optimal cooling can be achieved when the camera is situated in a downward-looking position with free airflow around its fins. At an ambient temperature of 25°C, the camera's default set point will be -10°C.

PVCAM Error Message Appears

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

Lengthy Pauses During Imaging

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

- Close any other programs that may be running.

- Install more physical memory (RAM) in your computer system.

Basic Specifications

**Camera
Dimensions
(Front)**

4.50 in
(11.43 cm)

(2) Holes
.15 in (.38 cm) dia x .15 in (.38 cm) deep
1.25 in (3.18 cm) apart

(2) Setscrews
.050 hex key

Adjustable
C-Mount Adapter
.215 in (.55 cm) travel in
adapter threads

C-Mount Adapter Thickness
Cascade:650 .265 in (.67 cm)
Cascade:1K .325 in (.83 cm)

4.00 in
(10.16 cm)

4.30 in
(10.92 cm)
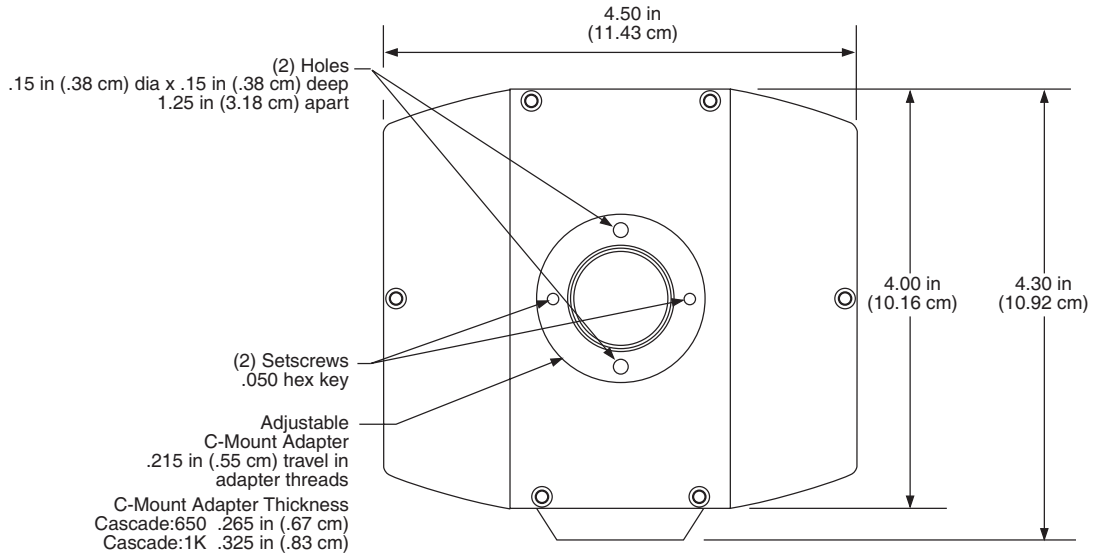
Cascade:650 and 1K Cameras – Front View

4.50 in
(11.43 cm)

(2) Holes
.15 in (.38 cm) dia x .15 in (.38 cm) deep
1.25 in (3.18 cm) apart

(2) Setscrews
.050 hex key

4.00 in
(10.16 cm)

4.30 in
(10.92 cm)

2.55 in
(6.48 cm)
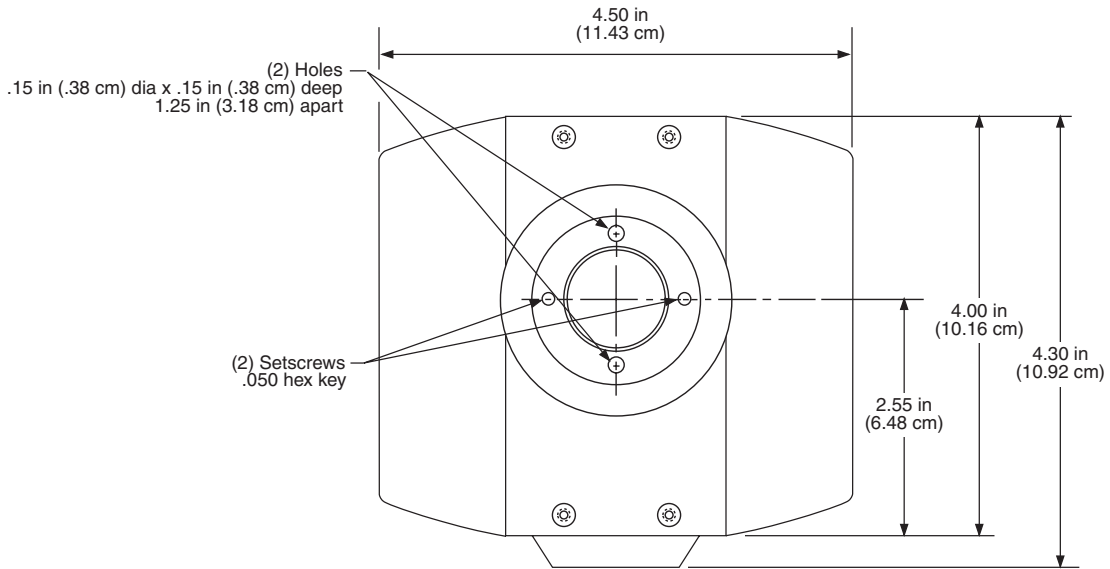
Cascade:512F, 512B, and 128+ Cameras – Front View
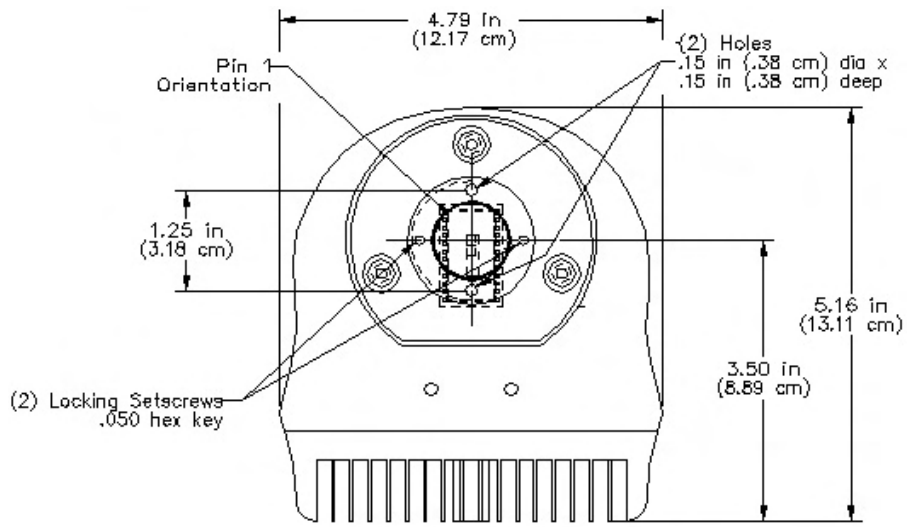
Cascade:128 Camera – Front View

**Camera
Dimensions
(Bottom)**

2.90 in
(7.37 cm)

7.01 in
(17.8 cm)

7.19 in
(18.26 cm)
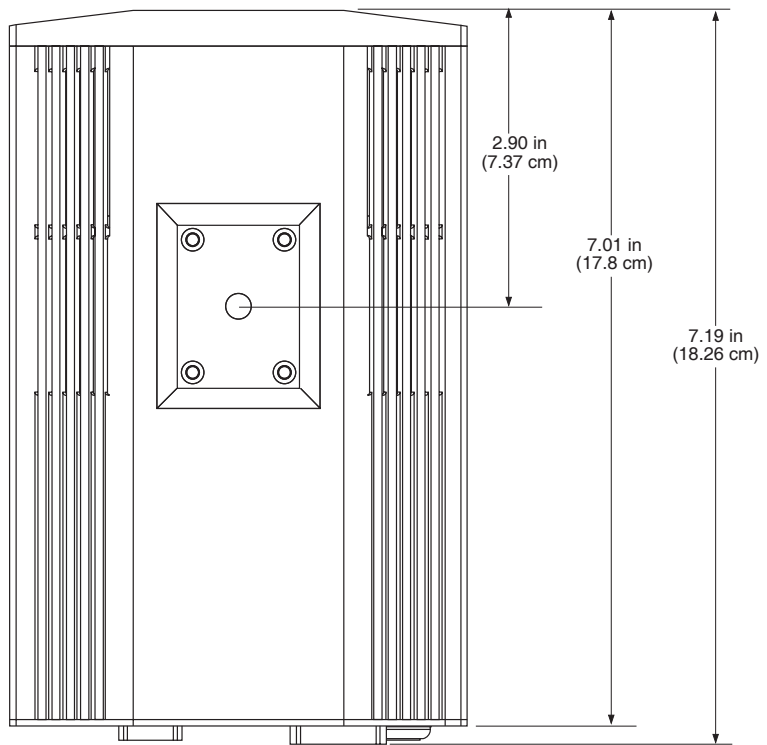
Cascade:650 Camera: Bottom View

2.90 in
(7.37 cm)

7.02 in
(17.83 cm)

7.20 in
(18.29 cm)
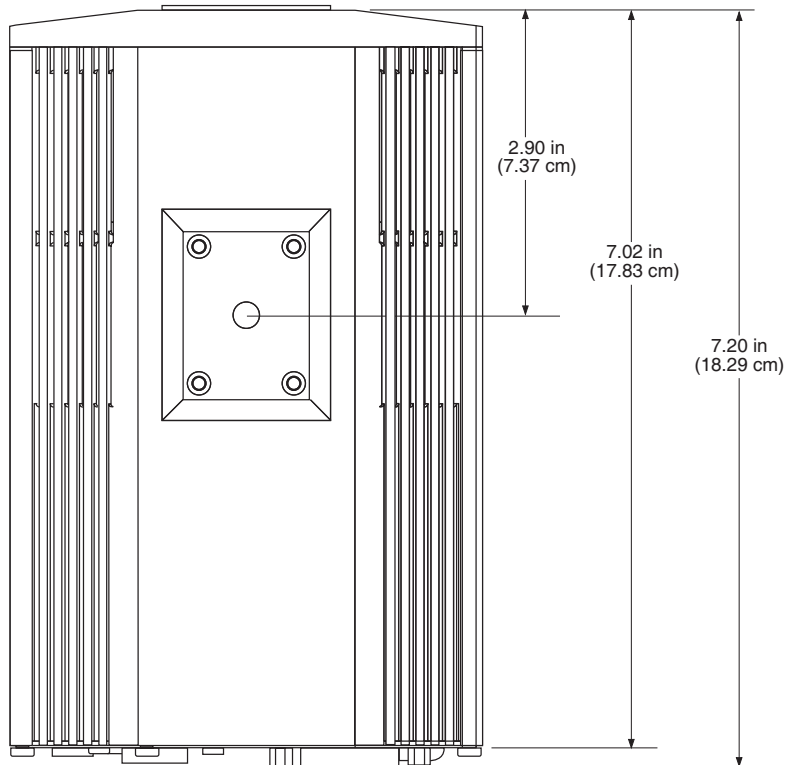
Cascade:1K Camera: Bottom View

.09 in
(.23 cm)

2.87 in
(7.29 cm)

6.98 in
(17.73 cm)

7.17 in
(18.21 cm)

1/4-20 UNC-2B thread
.30 in (.76 cm) max deep
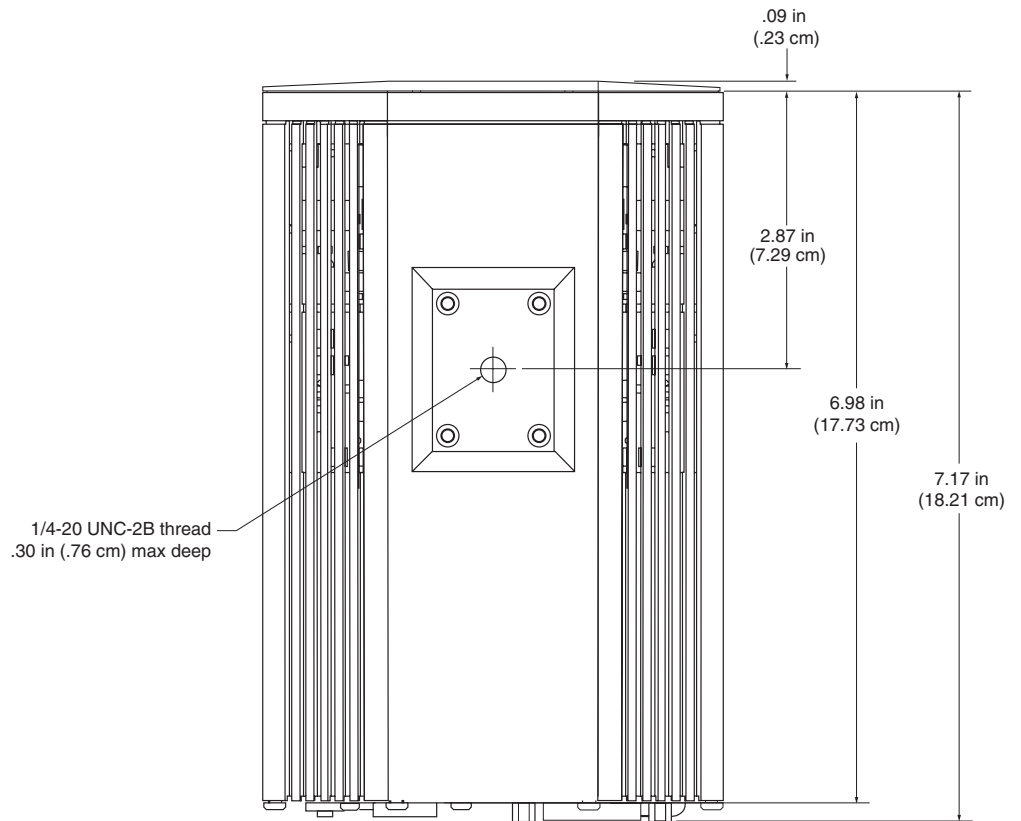
Cascade:512F, 512B, and 128+ Cameras: Bottom View

2.53 in
(6.43 cm)

7.24 in
(18.39 cm)

7.38 in
(18.75 cm)

1/4-20 UNC-2B THREAD
.40 in (1.02 cm) MAX DEEP
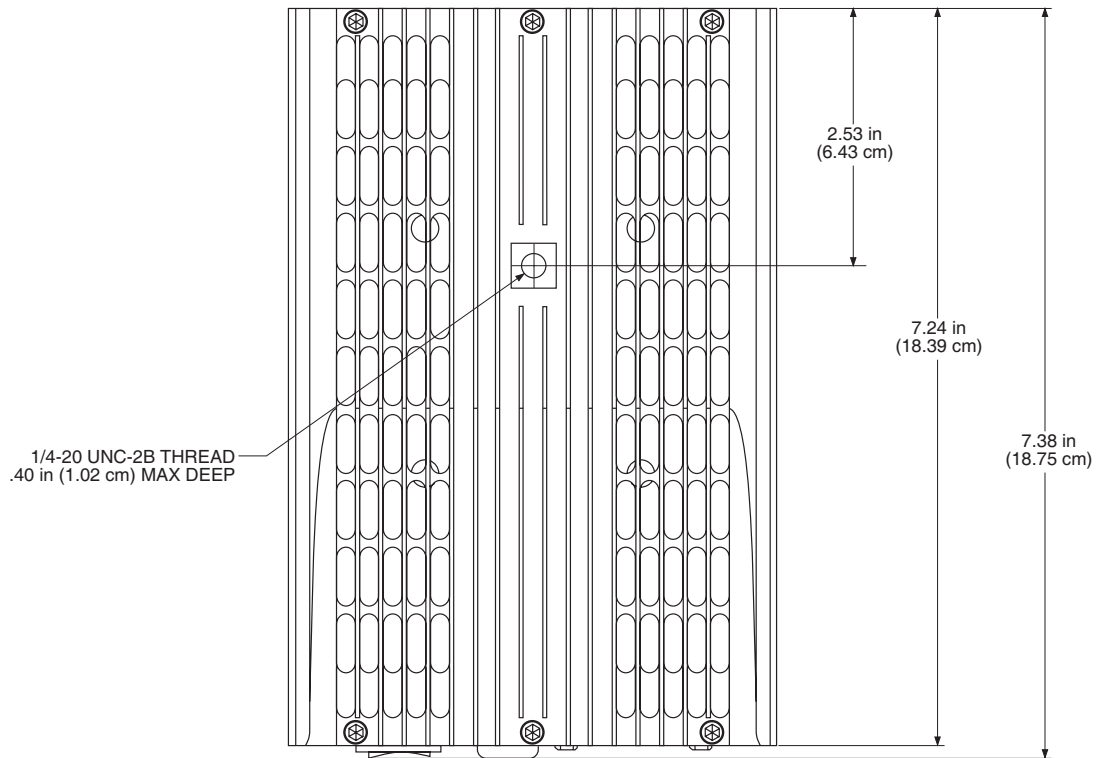
Cascade:128 Camera: Bottom View

Focal Plane Measurement

.66 in
(16.8 mm)
FOCAL PLANE
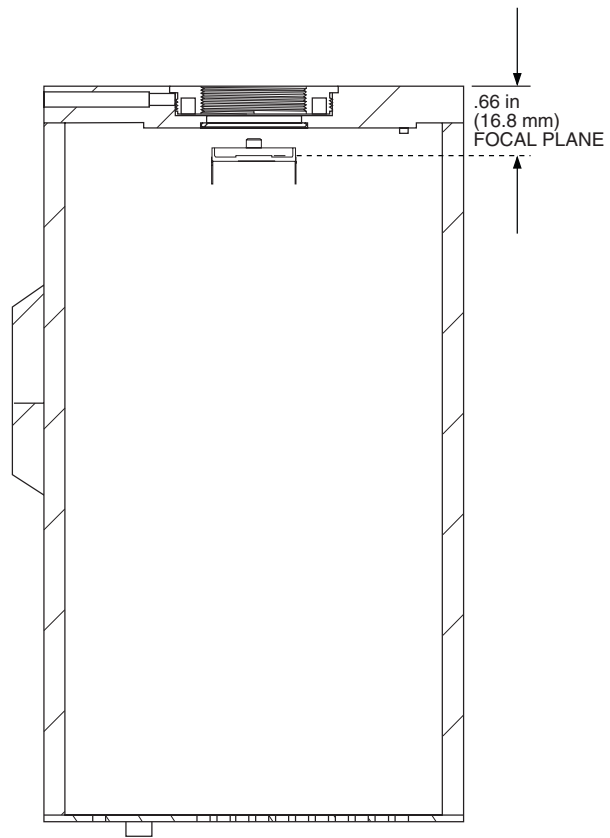
Cascade:650 Camera: Focal Plane

.61 in
(15.5 mm)

FOCAL PLANE

.66 in
(16.8 mm)
MECHANICAL
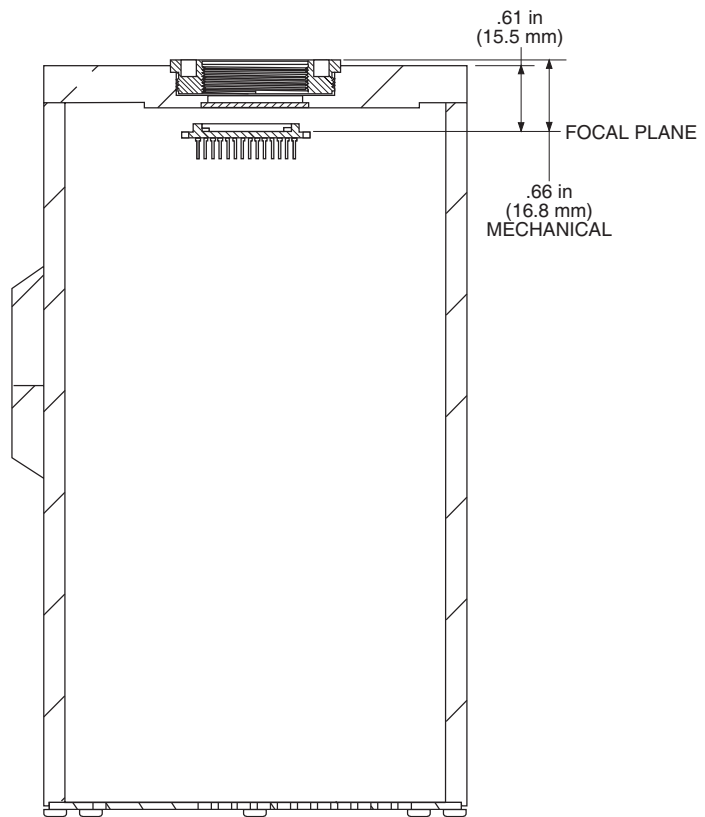
Cascade:1K Camera: Focal Plane

FOCAL PLANE

.63 in
(16.0 mm)
MECHANICAL
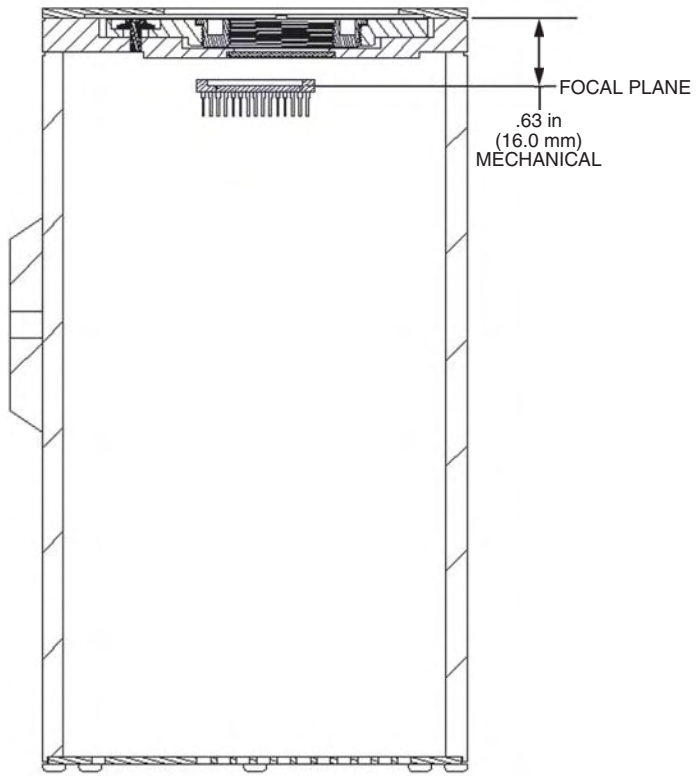
Cascade:512F and 512B Cameras: Focal Plane

.58 in
(14.7 mm)

FOCAL PLANE

.63 in
(16.0 mm)
MECHANICAL

Cascade:128+ Camera: Focal Plane

.080 in (2.0 mm) Adjustment

FOCAL PLANE

.65 in (16.5 mm) Mechanical
.70 in (17.8 mm) Optical
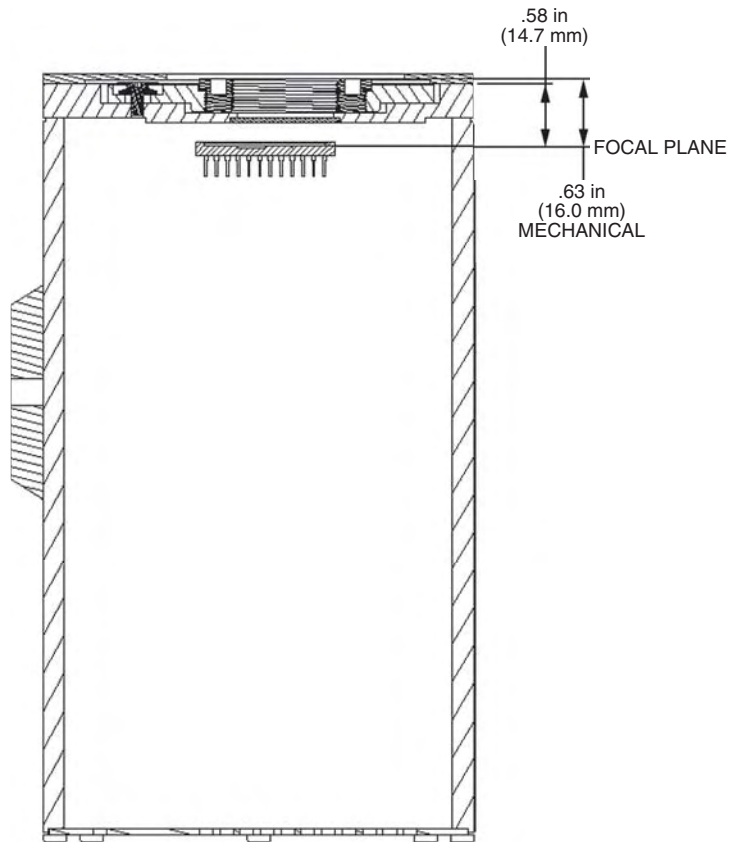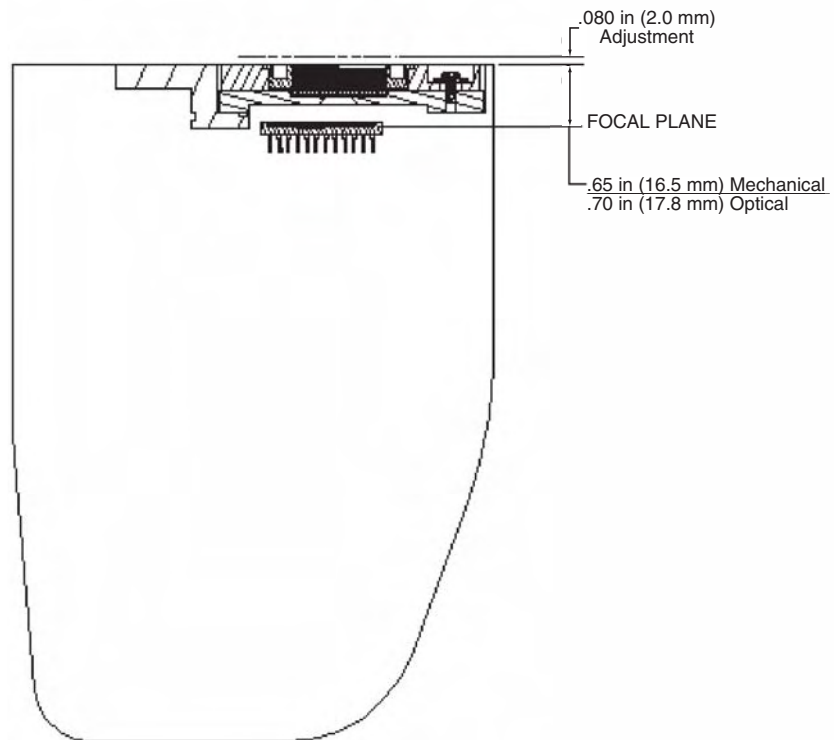
Cascade:128 Camera: Focal Plane

Additional Measurements

Camera weight:

Cascade:650, 1K, 512F, 512B, and 128+	6.5 lb. (2.9 kg)
Cascade:128	5.9 lb. (2.6 kg)

CCD Specifications and Orientation

	Cascade:650	Cascade:1K	Cascade:512F/ Cascade:512B	Cascade:128+	Cascade:128
CCD:	TI TC253	TI TC285SPD	E2V CCD87F E2V CCD97B	E2V CCD60	E2V CCD60
Image Type:	Monochrome	Monochrome	Monochrome	Monochrome	Monochrome
Resolution:	653 x 492	1004 x 1002	512 x 512	128+x128+	128x128
Pixel Size:	7.4 µm x 7.4 µm	8 µm x 8 µm	16 µm x 16 µm	24 µm x 24 µm	24 µm x 24 µm
Readout Amplifiers (Ports):	1	1	2	1	1
Digitization Rate:	10 MHz, 5 MHz	10 MHz	10 MHz, 5 MHz, 1 MHz	12 MHz	10 MHz
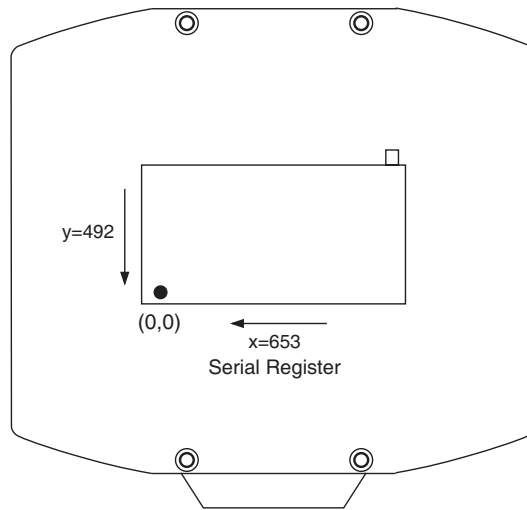
Cascade:650 CCD Orientation
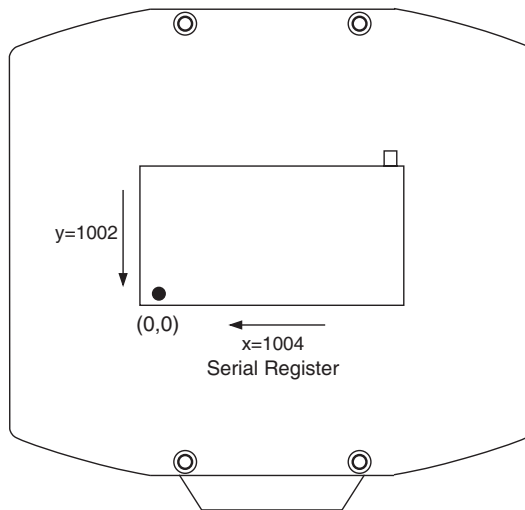
Cascade:1K CCD Orientation
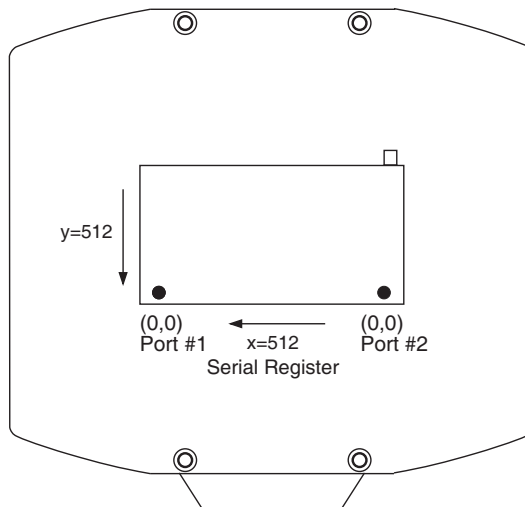
Cascade:512F/512B CCD Orientation
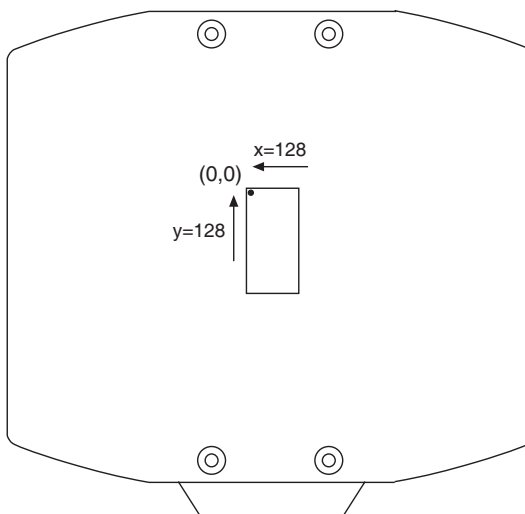
Cascade:128+ CCD Orientation
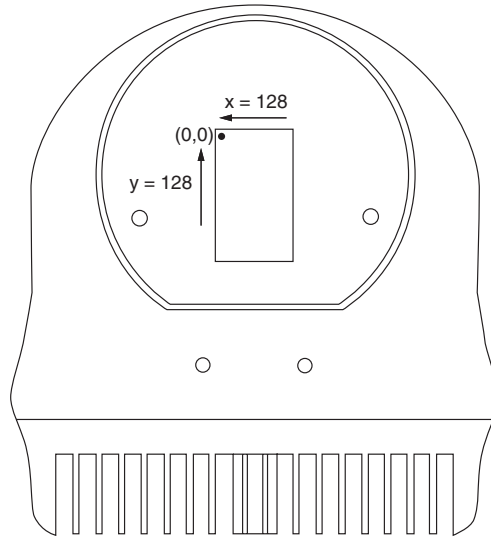
Cascade:128 CCD Orientation

Connectors

Cascade Rear Panels (Cascade:128 on right)

The following connectors are located on the back of the camera.

DATA connector: 20-pin, high-density connector for data transfer and power.

POWER connector: 5-pin, LEMO connector for camera power.

I/O connector: DB26, high-density connector for input/output control signals.

Note: Connectors and I/O signals are the same for all Cascade cameras.

**POWER Connector
Pinout**
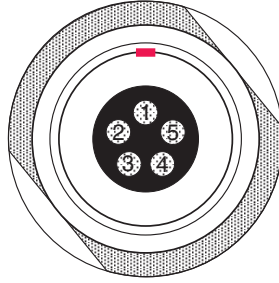
1. +12V
2. +12V
3. GND
4. GND
5. GND

I/O Connector Pinout
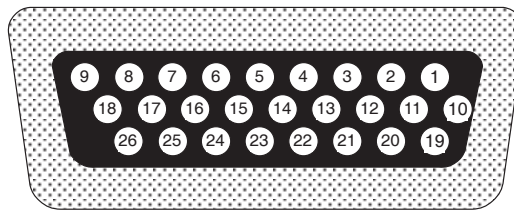
The I/O (Input/Output Status) connector provides information about trigger function, DAC, and TTL signals. Inputs must be at least 3.15 V for a high and less than 0.9 V for a low.

The numbers on the I/O connector diagram correspond to the numbers given to the definition of each of the pins. The I/O connector is a female, DB26, high-density connector. An I/O cable (Part #: 37-107-002) to access Trigger Input (Pin 1), Trigger Invert Input (Pin 2), Frame Readout (Pin 7), Camera exposing output (Pin 8), and Shutter Output (Pin 23) is available from Photometrics.

1   Trigger Input: This input is internally tied high through a 4.7kΩ resistor. With Trigger Invert Input open or tied high, a rising edge of the Trigger Input signal initiates the trigger. The trigger source would normally hold this input low, then drive it high to initiate the trigger. To change the state of this input see Trigger Invert Input.

2   Trigger Invert Input: This input is internally tied high through a 4.7kΩ resistor. With this input open or tied high, a rising edge on Trigger Input will initiate the trigger. With this input pulled low, a falling edge on Trigger Input will initiate the trigger. It can be pulled low by grounding it via a 50Ω terminator.

3   GND: System digital ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.

Port 4   **4   DAC 1:** 8-bit programmable output (0-5 V)

Port 5   **5   DAC 2:** 8-bit programmable output (0-5 V)

6   GND: System digital ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.

7   Frame Readout: Active high. A high level on this output indicates that data is being transferred.

8   Camera Exposing Output: Active high. A high level on this output indicates that the camera is exposing (integrating).

9   (not used)

Port 0   **10   TTL I/O data bit 0:** TTL level programmable input or output
11   TTL I/O data bit 1: TTL level programmable input or output

Port 1   **12   TTL I/O data bit 0:** TTL level programmable input or output
13   TTL I/O data bit 1: TTL level programmable input or output

Port 2   **14   TTL I/O data bit 0:** TTL level programmable input or output
15   TTL I/O data bit 1: TTL level programmable input or output

Port 3   **16   TTL I/O data bit 0:** TTL level programmable input or output
17   TTL I/O data bit 1: TTL level programmable input or output

18   GND: System digital ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.

19   Power Status: A high level on this output indicates that the camera power is switched on (+5 V = on, 0 V = off).

20   GND: System digital ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection

21   (not used)

22   (not used)

23   Shutter Output: TTL output for timing of external shutter driver. Signal is high during Shutter Open Delay and exposure time. The pin does not provide power to drive the shutter directly, so an external shutter drive controller is required.

24   (not used)

25   GND: System digital ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.

26   GND: System digital ground. Any external circuitry intended to interface with the trigger control signals must reference this ground connection.

Power Supply Specifications and Dimensions

Voltage Input: 100-240 V~ @ 47-63 Hz

Current Input: 3.0 A

Voltage Output: +12 Vdc

Maximum Power Output: 96 W
Power Supply Weight: 2 lb (0.9 kg)

Note: CE certification applies to the Cascade only when the camera system is operated with a CE-approved power supply.
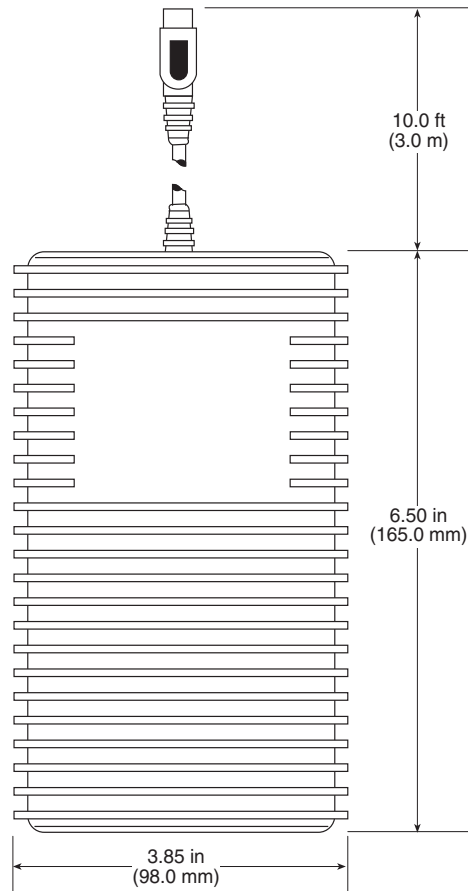
Power Supply: Top View
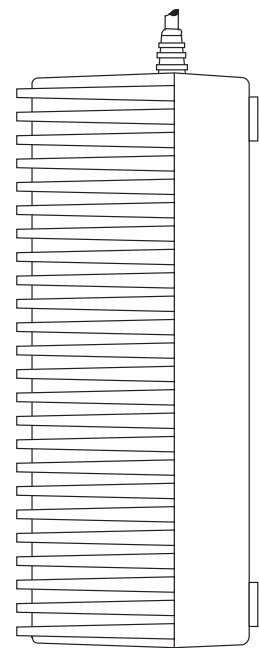
Power Supply: Side View
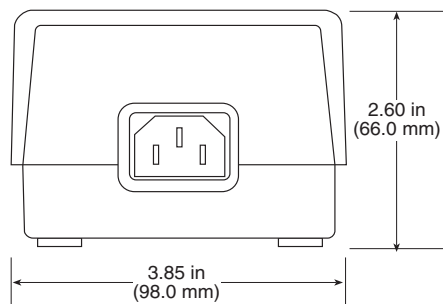
Power Supply: Front View

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