Princeton Instruments

I-PentaMAX™ System

Princeton Instruments
a division of Roper Scientific, Inc.

Camera Detection Wizard

Introduction

Version 2.5.19.6 of the WinX software (WinView, WinSpec, and WinXTest) introduced enhancements to the former Hardware Setup Wizard. Now called the Camera Detection Wizard, this function is used to load the WinX hardware setup parameter fields with default values for a WinX-compatible camera system. The Camera Detection Wizard runs automatically the first time you install WinX and can be launched at a later date if you decide to control a different WinX-compatible camera. The autodetection function can be used for both PVCAM-based camera systems (USB 1 interface, USB 2 interface, Photometrics PCI, PhotonMAX) and Princeton Instruments RS PCI (TAXI) interface-based systems.

Changes to the Software

- For PVCAM-based cameras (USB 1 interface, USB 2 interface, Photometrics PCI, PhotonMAX) ------- You no longer have to run the RSConfig.exe program --- this is done by the Camera Detection Wizard.

- **ALL** Win-X compatible camera systems can be set up via the autodetection function but only Princeton Instruments RS PCI (TAXI) interface-based systems can be set up using the manual function.

- The **PVCAM** dialog is no longer included in the wizard.
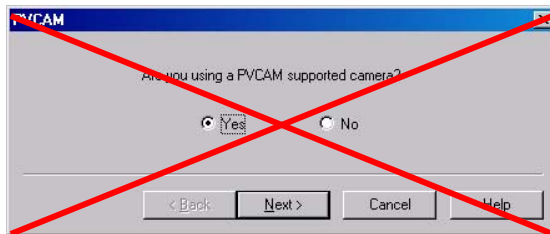
- The **Use PVCAM** checkbox is no longer present on the **Setup|Hardware|Controller/Camera** (or CCD) tab page.

- There is now a **Launch Camera Detection Wizard** button on the **Setup|Hardware|Controller/Camera** (or CCD) tab page.

Required by the Wizard

- You **MUST** use the autodetection mode for PVCAM-based cameras (USB 1 interface, USB 2 interface, Photometrics PCI, PhotonMAX). The function can also be used to detect Princeton Instruments RS PCI (TAXI) interface-based systems.

- Before you select autodetection, you must have connected the camera system to the host computer and have turned the camera system ON.

- Before selecting "Yes" for the Test Image, you must have connected the camera system to the host computer and have turned the camera system ON.
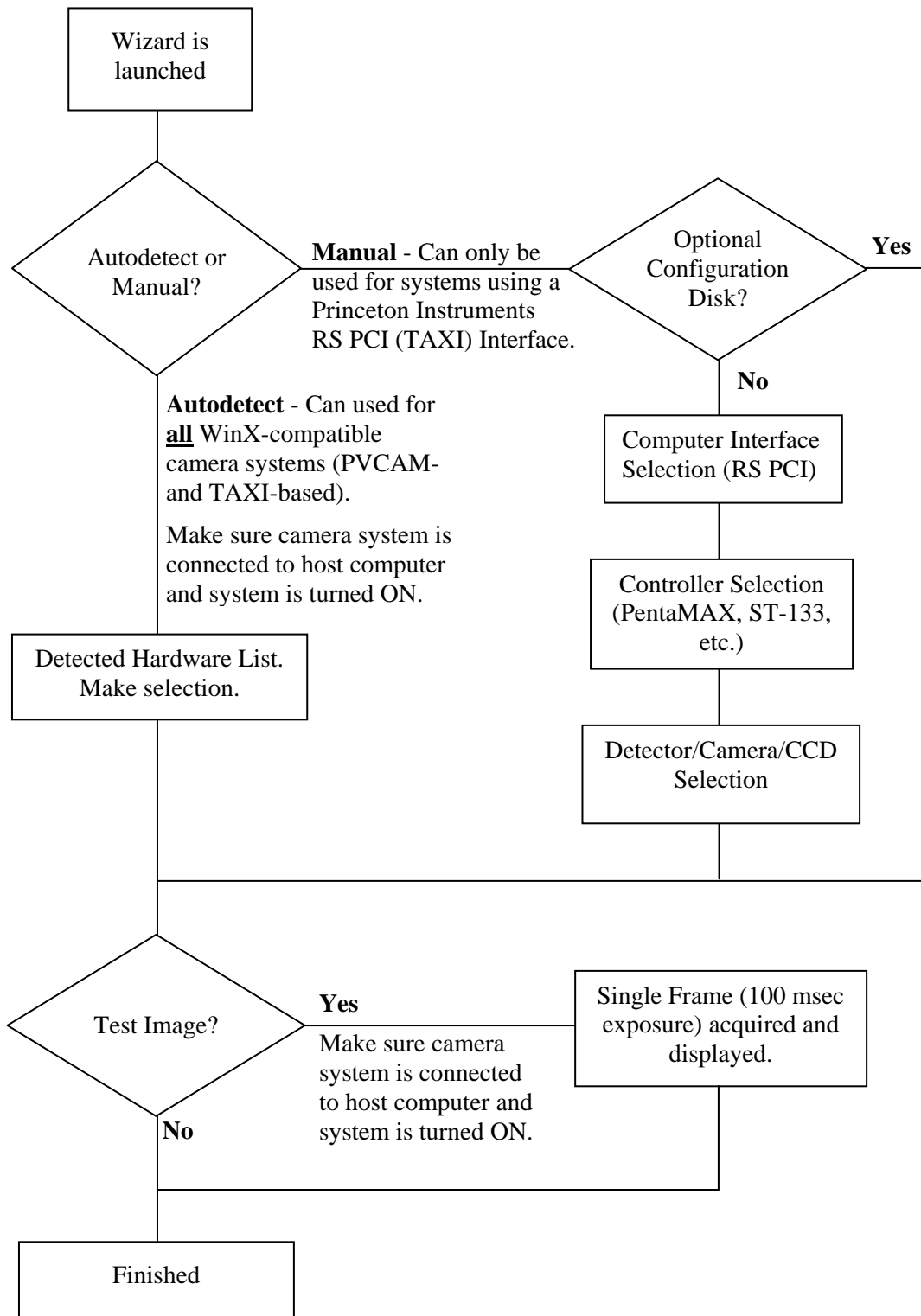
...SEE the Future

Camera Detection Wizard Flowchart

```
                    ┌─────────────┐
                    │  Wizard is  │
                    │  launched   │
                    └─────────────┘
                           │
                           │
            ◇ Autodetect or ◇───── Manual - Can only be        ◇ Optional        ─── Yes
              Manual?              used for systems using a       Configuration
                                   Princeton Instruments          Disk?
                                   RS PCI (TAXI) Interface.         │
                                                                   No
            Autodetect - Can used for
            all WinX-compatible                              ┌─────────────────┐
            camera systems (PVCAM-                           │Computer Interface│
            and TAXI-based).                                 │Selection (RS PCI)│
                                                             └─────────────────┘
            Make sure camera system is
            connected to host computer                       ┌─────────────────┐
            and system is turned ON.                         │Controller Selection│
                                                             │(PentaMAX, ST-133,│
            ┌─────────────────┐                              │     etc.)        │
            │Detected Hardware List.│                        └─────────────────┘
            │ Make selection.  │
            └─────────────────┘                              ┌─────────────────┐
                                                             │Detector/Camera/CCD│
                                                             │   Selection     │
                                                             └─────────────────┘

            ◇ Test Image? ◇──── Yes            ┌─────────────────┐
                                Make sure camera │Single Frame (100 msec│
                                system is connected│exposure) acquired and│
                   No           to host computer and│   displayed.    │
                                system is turned ON.└─────────────────┘

            ┌─────────────┐
            │  Finished   │
            └─────────────┘
```

E:\Manuals\Tech Notes\Camera Detection Wizard supplement.doc

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Introduction

Figure 1. I-PentaMAX System

Description

The Princeton Instruments I-Penta*MAX* System consists of an intensified camera, an external temperature controller/power supply, a computer, a high-voltage power supply and the necessary system cables. It is designed for general macro-imaging and microscopy imaging applications at both low and medium light levels. In operation, data acquired by the camera is routed to the computer for processing and display. A composite video output is also provided to allow immediate viewing of the acquired images on a separate monitor. The computer controls both the system configuration and data acquisition via software, of which Princeton Instruments WinView is an example.

The camera is fitted with a microchannel plate (MCP) image intensifier fiber-optically coupled to a CCD array. A window at the front of the intensifier seals the intensifier and array into an integrated chamber maintained at a positive pressure. The enclosure is normally pressurized with dry air to about 1 psi. Power to the intensifier is supplied by a high voltage power supply (IIC-100, IIC-200, or IIC-300) or by the MCP-100 (gate pulser option) via a high voltage cable. The connector for the high-voltage cable is located on the side of the intensifier housing.

The I-Penta*MAX* Camera combines both high-speed and high-precision readout capabilities. It can collect 12 bit images at a readout rate of up to 5 million pixels per second (5 MHz) in the high-speed mode or at 1 million pixels per second (1 MHz) in the optional precision mode. The speed and resolutions of the two data collection modes provided are matched to the capabilities of the CCD sensor (see Appendix A). Two complete analog channels, each with its own A/D converter (precision A/D converter optional), are provided for optimum signal-to-noise ratios in both readout modes.

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Switching between the two channels is completely under software control for total experiment automation. Data is transferred directly to the host computer memory via a high-speed serial link. Standard composite video, either RS-170 (EIA) or CCIR, whichever was ordered, is also provided.

The camera interfaces to a host computer via a high-speed serial link (twisted pair or fiber optic cable) for immediate data transfer to computer memory. The optional fiber optic connection allows the computer to be remotely located at distances as great as two kilometers with no signal degradation.

There is provision for extremely flexible readout of the CCD. Readout modes supported include full resolution, simultaneous multiple subimages, and nonuniform binning. Single or multiple software-defined regions of interest can also be tested without having to digitize all the pixels of the array. Completely flexible exposure, set through software, is also fully supported.

Power for the camera comes from a separate temperature controller/power supply unit, which can be located up to 15 feet from the camera. This unit features a digital display for setting the CCD temperature and for monitoring the current CCD temperature. Front-panel indicators continuously indicate the temperature control status.

With its fully integrated design, advanced exposure control timing, and sophisticated readout capabilities, the I-Penta*MAX* system is well suited to low light macro imaging and microscopy applications.

About this Manual

Manual Organization

This manual provides the user with all the information needed to install an I-Penta*MAX* system and place it in operation. Topics covered include a detailed description of the camera, the temperature/power supply unit, installation, cleaning, specifications and more.

Chapter 1, Introduction briefly describes the I-Penta*MAX* system; details the structure of this manual; and documents environmental, storage, and cleaning requirements.

Chapter 2, Installation Overview cross references system setup actions with the relevant manuals and/or manual pages. It also contains system layout diagrams.

Chapter 3, Hardware Setup provides detailed directions for installing the interface card and for interconnecting the system components.

Chapter 4, Temperature Control discusses how to establish and maintain temperature control.

Chapter 5, First Light discusses how to focus the camera.

Chapter 6, Microscopy Applications discusses the setup and optimization of your digital imaging system as applied to microscopy.

Chapter 7, Intensifier provides an overview of intensifier operation and describes the function of the overload detection circuitry and the intensifier alarm.

Chapter 8, Timing Modes discusses the basic camera timing modes and related topics, including Full Speed vs. Safe Mode, Free Run, External Sync, Continuous Cleans.

Chapter 9, Exposure and Readout discusses Exposure and Readout, together with many peripheral topics, including saturation, dark charge, binning and frame-transfer readout.

Chapter 10, Troubleshooting provides information regarding possible system hardware problems.

Appendix A, Specifications includes camera specifications.

Appendix B, Outline Drawings of Camera & Temperature/Power Supply provides size information for these units.

Appendix C, PentaMAX Versions summarizes PentaMAX capabilities by version.

Appendix D, Two-Shot Kinetics Mode describes the 2-shot kinetics mode for the Penta*MAX* 512x512FT camera, Version 5.

Appendix E, Virtual Chip Mode describes virtual chip operation and provides a setup procedure.

Warranty & Service details the limited warranties for Princeton Instruments cameras and software. Contact information for assistance and service is also provided.

Safety Related Symbols Used Manual

Caution! The use of this symbol on equipment indicates that one or more nearby items should not be operated without first consulting the manual. The same symbol appears in the manual adjacent to the text that discusses the hardware item(s) in question.

Caution! 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.

Camera Features

Camera Front

The intensifier and lens mount housing are at the front of the camera. The details of the housing can vary depending on the type of mount and on the type of CCD array installed. If the lens mount adapter is purchased at the same time as the I-Penta*MAX*, the camera will be supplied with the adapter installed. A C-mount lens adapter is standard.

The connector for the high-voltage cable is located on the intensifier housing. This cable is supplied with the high voltage supply and must be connected for the intensifier to function. Without high voltage applied, the intensifier is completely blind. Chapter 5 discusses operation of the camera, including connecting the high voltage cable and high-voltage operating considerations.

DANGER

The high voltage cable carries *lethal* voltages to the image intensifier (as much as 10,000 Volts). *Never* turn on the high-voltage power supply (IIC-100 or IIC-200) or the pulser equipped with the MCP-100 modular high-voltage supply unless both ends of the high voltage cable are connected. These ends should be tightly connected to the mating connections or arcing could occur and damage the intensifier. A cable connected at one end only is not only hazardous, but is susceptible to arcing and subsequent erratic operation due to the formation of carbon tracks.

WARNING!

The high voltage cable should be handled with care. Dropping the cable or banging the connectors may damage the pins, resulting in a poor or intermittent connection, which could result in damage to the intensifier.

Camera Back Panel

The camera's connectors and coolant ports are located on the back panel as shown in Figure 2. A brief description of each feature follows.

Fan: There is an internal fan located behind the back panel next to the ventilation grill. Its purpose is:

- to remove heat from the Peltier device that cools the CCD array, and,

- to cool the electronics.

This fan runs continuously whenever the camera is powered. It is designed for low-vibration and does not adversely affect the image. For the fan to function properly, free circulation must be maintained between the laboratory atmosphere and the rear and sides of the camera.

WATER Cooling Ports: There is provision for liquid cooling via the two barbed cooling fittings at the rear panel. The liquid cooling option is provided for use when the camera is placed in an environment where dynamic airflow is restricted or the ambient environment of the camera is 35°C or higher. We strongly advise users to see Chapter 4, *Temperature Control* before making any connections to the liquid cooling ports.
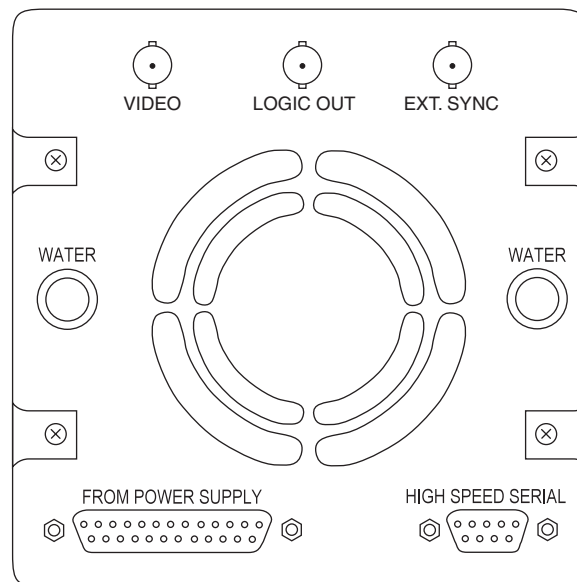
Figure 2. Camera Back Panel

FROM POWER SUPPLY Connector: The cable that interconnects the Camera and the Temperature/Power Supply unit connects to this 25-pin connector. This connector, the cable, and the corresponding connector on the Temperature/Power Supply unit are configured so that the cable cannot be installed incorrectly. However, it is essential that the cable connector locking screws be tightened securely to ensure reliable operation. Note that this is a proprietary cable; a generic off the shelf cable cannot be substituted.

CAUTION	Always have the power off when connecting or disconnecting the Camera to Power Supply cable.

HIGH SPEED SERIAL Connector: The cable that goes from the Camera to the computer connects to this 9-pin connector. Again, it is essential that the cable connector locking screws be tightened securely to ensure reliable operation. If the application requires use of the optional fiber-optic data link to increase the maximum allowable distance between the Camera and the computer, the fiber-optic "pod" would be connected to the HIGH SPEED SERIAL connector with a short length of cable. Then the long distance fiber-optic cable would be connected to the pod. *A similar fiber-optic pod connection is required at the computer.*

The computer connection at the other end of the cable depends on the computer type. *See Chapter 3 for detailed information.*

VIDEO BNC Connector: This is the composite video output. The amplitude is 1 V pk-pk and the source impedance is 75 Ω . Either RS-170 (EIA) or CCIR standard video can be provided and must be specified when the system is ordered. The video should be connected to the monitor via a 75 Ω cable and it must be terminated by 75 Ω . Many monitors have a selector switch to select either terminated or unterminated operation.

Since the image is available at the computer via WinView, use of a separate video monitor isn't essential. Note, however, that the monitor view is updated as fast as the data can be transferred. At the computer, because of the software overhead, the image is updated more slowly. As a result, for operations such as focusing, where it is advantageous to track changes as fast as possible, the video output is much preferred.

The video output is selected by the Application software. In the case of WinView, this is done by selecting RS170 from the Acquisition menu. Since the view afforded by the video monitor is limited and fixed, all of the pixels from an array may not be displayed. For example, some of the image from a 512×512 array will be cropped when viewed on a 756×486 RS-170 monitor (NTSC format). When this is the case, WinView's Video Focus functionality allows you to display the entire image at reduced resolution or to pan to a subset of the array image.

> **Note:** If more than one device is connected to the video output, the *last* device is the one that should to be terminated in 75 Ω. For example, to connect the video output to a VCR as well as to a monitor, the cable from the controller video output should be connected to the video input connector of the VCR, and another 75 Ω cable should extend from the video output connector of VCR to the 75Ω input of the monitor. Do *not* use a BNC TEE to connect the controller video output to multiple devices.

LOGIC OUT BNC Connector: This TTL output (formerly labeled **NOTSCAN**) is provided to allow monitoring of the camera's status. The camera state reported at this connector is selected by the application software. A brief description of the available signals follows.

NOTREADY: After a Start Acquisition command, this output signal changes state on completion of the array cleaning cycles that precede the first exposure. Initially high, **NOTREADY** goes low to mark the beginning of the first exposure. In free run operation it remains low until the system in halted. If a specific number of frames have been programmed, it remains low until all have been taken, then returns high.

NOTSCAN: Reports when the controller is finished reading out the CCD array. **NOTSCAN** is high when the CCD array is not being scanned, then drops low when readout begins, returning to high when the process is finished. It is also low during cleaning of the CCD. See *Chapter 8*, *Timing Modes,* for additional information.

SHUTTER: This signal is low when the shutter is closed and goes high when the shutter is activated, dropping low again after the shutter closes. See *Chapter 8, Timing Modes,* for additional information.

In gated operation, this signal is used to inhibit the pulser when the array is being read out. Therefore, even with a frame-transfer CCD, a full-frame timing mode should be used for gated operation. With an FG-100 or FG-100H pulser, this is done by connecting the **SHUTTER** signal to the pulser's **ENABLE** input. In the case of a PG-200 pulser, the **SHUTTER** signal would be connected to the **INHIBIT** input.

In shutter-mode operation (set at the high-voltage power supply), the **SHUTTER** signal could be connected to the **SHUTTER IN** connector on the IIC-200 (IIC-300, IIC-100, or MCP-100), allowing exposures from 50 µs to 23 hours to be obtained. With no connection to the **SHUTTER IN** connector (operating in shutter mode), the intensifier will be **ON** continuously.

CLEANING: This signal is high when an array Clean cycle is in progress and otherwise low.

FT IMAGE SHIFT: This signal is low when a frame transfer shift is in progress and otherwise high. This signal can be used to control fast wavelength switching devices in microscopy applications.

LOGIC 0: Establishes a TTL logic 0 at the **LOGIC OUT** connector.

LOGIC 1: Establishes a TTL logic 1 at the **LOGIC OUT** connector.

Note: LOGIC 0 and LOGIC 1 can be used to control an external device using the application software.

EXT SYNC BNC Connector: This TTL input allows data acquisition to be synchronized with external events. The sense can be positive or negative (set via software). *See Chapter 8*, *Timing Modes*.

CCD and Intensifier Enclosure

The camera is shipped backfilled to 1 psi (gauge), which is good for the lifetime of the camera. If the camera intensifier/CCD enclosure should accidentally be opened to the atmosphere, immediately shut down the system. Contact Princeton Instruments Customer Support for further instructions.

WARNING!

Operating an I-Penta*MAX* camera that is no longer backfilled with dry air or nitrogen may result in condensation on the array and intensifier that could cause irreversible damage. Such damage would not be covered by the warranty.

Temperature/Power Supply Unit Features
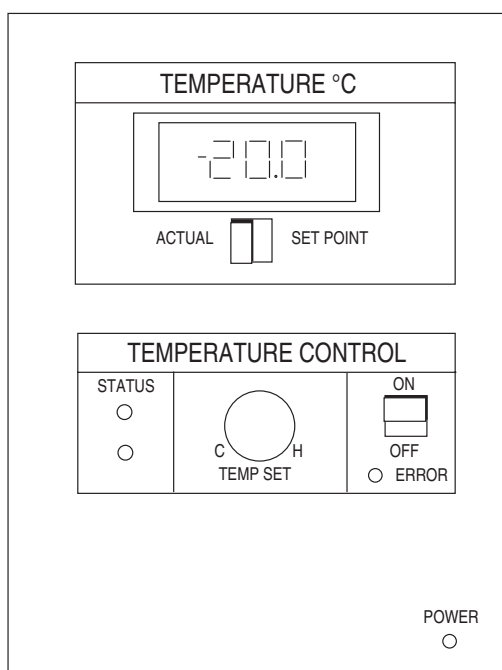
Figure 3. Temperature/Power Supply Front Panel

Temperature/Power Supply Front Panel
TEMPERATURE (°C) Panel Meter: This LCD panel meter displays either the set temperature or the actual temperature. Note that the temperature range that can be set extends beyond that which can be achieved. Typically, it is possible to achieve temperature lock down to about -20°C in air-cooled operation, and a few degrees colder with supplemental liquid cooling. Setting an out-of-range temperature such as -70°C, for example, won't harm the camera but it will be impossible to establish temperature lock, necessary for good measurement repeatability. *Operating with the temperature out of range for a long time might cause the camera to overheat and shut down. See Chapter 4.*

It is important to note that, even though the system controls to within ±0.04° for outstanding measurement repeatability, the indicated set and actual temperature

may still differ slightly once temperature lock has been established, typically by 0.1° C. This difference stems from the panel-meter limitations.

ACTUAL vs. SET POINT Switch: This switch allows the user to choose either the Set Point temperature or the Actual temperature for display.

TEMP SET Knob: This knob directly sets the temperature at which the CCD array will be controlled. That temperature will be displayed on the Temperature Display meter when the Actual vs. Set Point switch is set to **SET POINT.** Turning the knob counterclockwise, towards **C**, sets a colder temperature. Turning it clockwise, towards **H**, sets a warmer temperature. Note that the Temperature Set knob is equipped with a friction lock. This high turning resistance ensures that the setting will not inadvertently change due to vibration or accidental contact.

ON - OFF Switch: Setting this switch to ON switches on the temperature control function, causing one of the two temperature Status indicators to light, as described in the following paragraph. If the red **ERROR** indicator lights, there is an error condition that has to be corrected before temperature-control operation can be established. *Error conditions are discussed in Chapter 4.*

STATUS Indicators: There are two, one yellow, the other green. The yellow one lights to indicate that the temperature controller is active (On/Off switch to ON) but that temperature lock has not yet been established. The green one lights when temperature lock has been established. As long as the temperature-control function is active, one or the other of these indicators will light, but never both at the same time.

ERROR Indicator: Lights when there is a temperature-control error condition that must be corrected before the temperature control loop can function properly. Once an error indication occurs, it is *always* necessary to cycle the I-Penta*MAX* power before normal operation can be established. Even if the source of the error is corrected while the system is still powered, the error condition will continue to be indicated until the power is cycled. Again, Chapter 4, *Temperature Control,* contains a detailed discussion of the possible causes of a temperature-control error indication and the appropriate remedial action to take for each.

POWER Indicator: Lights whenever the I-Penta*MAX* is powered. The Power switch is located on the back panel of the Temperature/Power Supply unit.

Temperature/Power Supply Back Panel

Fan: The internal fan that cools the Temperature/Power Supply electronics is located directly behind the back-panel grill. This fan runs continuously whenever the power is on. For proper operation, it is essential that free circulation be maintained between the rear of the power supply and the laboratory atmosphere. If the airflow becomes restricted, it could cause an over-temperature condition in the power supply that would cause it to shut down, interrupting system operation.

TO CAMERA Connector: The cable that interconnects the Temperature/Power Supply and the Camera connects to this 25-pin connector. This connector, the cable, and the corresponding connector on the Camera are configured so that the cable cannot be installed incorrectly. However, it is essential that the cable connector locking screws be tightened securely to ensure reliable operation.

CAUTION

Again, the power should be off when connecting or disconnecting this cable to avoid placing your equipment at risk.

Power Input Assembly: This assembly contains the line-cord socket, the Power On/Off switch and the line fuse. The power requirements and fuse ratings are printed on the panel to the right of the assembly.

The plug on the line cord supplied with the system should be compatible with the line-voltage outlets commonly used in the region to which the system is shipped. If the line cord plug should prove to be incompatible, a compatible plug should be installed, taking care to maintain the proper polarity to protect the equipment and assure user safety.
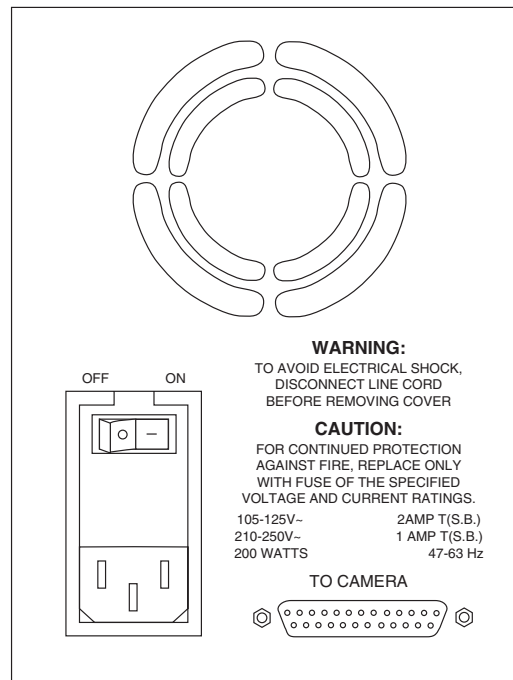
Figure 4. Temperature/Power Supply Back Panel

The On/Off Power rocker switch determines whether AC power will be available to the Temperature/Power Supply. As indicated on the panel, pressing the left end of the switch selects OFF and pressing the right end of the switch selects ON.

Note that there is no provision for setting the operating line voltage. None is required because the I-Penta*MAX* Temperature/Power Supply unit auto-senses the applied voltage and automatically configures itself accordingly.

However, the line fuse value does depend on the line voltage as indicated to the right of the Power Input assembly. As mentioned in the discussion of Power Requirements on page 26, the Power Input assembly cover can be easily removed to gain access to the fuse so that one of the appropriate value can be installed.

Temperature/Power Supply Filter

On the bottom of the Temperature/Power Supply unit is a small recess containing a foam filter. The supply's internal fan draws ventilation air in through this filter, circulates it past the internal electronics and then exhausts it through the rear-panel grill. When the supply is resting on a typical hard surface with ready access between the ambient air and the air intake on the bottom of the supply, there is ample cooling reserve. If this access should be blocked, an over-temperature condition may develop, causing the temperature regulation circuitry to shut down. This could also happen if the filter becomes very dirty after long operation. For this reason, from time to time it is advisable to remove the filter and clean it. Refer to the Cleaning and Maintenance section for instructions.

CAUTION | Do not operate the Temperature/Power Supply unit with the filter removed.

Grounding and Safety

The apparatus described in this manual is of the Class I category as defined in IEC Publication 348 (Safety Requirements for Electronic Measuring Apparatus). It is designed for indoor operation only. Before turning on the Temperature/Power Supply unit, 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.

WARNING! | If the equipment is damaged, the protective grounding could be disconnected. Do *not* use damaged equipment until authorized personnel have verified its safety. 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 as that of the original ones to avoid hazard due to electrical shock.

ESD 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:

- When using high-voltage equipment (such as an arc lamp) with your I-Penta*MAX* system, be sure to turn the controller power *on last* and power the controller *off first*.

- Use caution when triggering high-current switching devices (such as an arc lamp) near your system. Transient voltage spikes can permanently damage the CCD. If electrically noisy devices are present, an isolated, conditioned power line or dedicated isolation transformer is highly recommended.

- Never connect or disconnect *any* cable while the I-Penta*MAX* system is powered on. An unconnected cable segment can become electrically charged and can damage the CCD if reconnected.

- Connect the camera-power supply cable to the Temperature/Power Supply unit before connecting the cable to the camera.

- Disconnect the camera-power supply cable from the camera before disconnecting it from the Temperature/Power Supply unit.

Additional Precautions

Camera and Temperature/Power Supply Unit
- Never impede airflow through the equipment by obstructing the air vents. Allow at least a one-inch air space around any vent.

- Do not "mix and match" cameras and Temperature/Power Supply units.

Image Intensifier Controller (IIC-200, IIC-300, and IIC-100)
- Before turning on the high voltage supply to the intensifier, turn MCP GAIN to 0 gain.

Environmental Requirements

- Storage temperature -20°C to 55°C

- Operating environment 0°C to 30°C

- Relative humidity ≤50%.

Computer Requirements

Host Computer Type

Note: Computers and operating systems all undergo frequent revision. The following information is only intended to give an approximate indication of computer requirements. Please contact the factory to determine your specific needs.

PC

Type: PCI-bus based Pentium (or better).

Memory (RAM): Minimum of 64 Mbytes; possibly more depending on experiment design and size of CCD Array.

Operating System: Windows® 3.1 or higher.

Interface: PCI High-Speed Serial I/O card. *PCI bus Computers purchased from Princeton Instruments as part of the I-PentaMAX system are shipped with the card installed.*

Power Macintosh®

Type: Power Macintosh with an available PCI card slot

Memory (RAM): Minimum of 4 Mbytes; possibly more depending on experiment design and size of CCD Array.

Operating System: System 6.0.5 or later. *IPLab™ is fully System 7 compatible, including up to System 7.5.*

Sun Workstation

Consult the factory.

SGI Workstation

Consult the factory

Application Software

The I-Penta*MAX* camera runs under WinView/32, Princeton Instruments' 32-bit Windows software package designed specifically for digital imaging. WinView/32 provides comprehensive acquisition, display, and processing functions. The WinView/32 package facilitates snap-ins to permit easy customization of any function or sequence. Windows DLLs are available to allow you to write your own software. The I-Penta*MAX* camera system is also supported by a host of third-party scientific imaging packages.

Cleaning and 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.

Temperature/Power Supply

Periodic cleaning of the Temperature/Power Supply unit filter is required to ensure adequate airflow through the unit.

To Clean the Air Filter:

1. Turn the Temperature/Power Supply unit **OFF** and unplug the unit from the AC power source.
2. Place the unit upside down.
3. Grasp the filter on the bottom of the unit and remove it.
4. Shake it to dislodge the dirt.
5. Reinstall the filter.
6. Return the unit to its upright position and plug it into the AC power source.

CAUTION

Do not operate the Temperature/Power Supply unit with the filter removed.

Optical Surfaces

The camera's optical window may need to be cleaned 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 than dragging the dampened tissue over the optical surface to be cleaned. Do not allow any other material to touch the optical surfaces.

Refer to your optics supplier for instructions on cleaning other optical surfaces.

WARNING!

⚠

There is nothing to clean on the inside of the nose assembly. Do not attempt to remove the nose assembly to access the intensifier. Such an action could damage the camera and void your warranty.

Repairs

Save the original packing materials. Because the I-PentaMAX system contains no user-serviceable parts, repairs must be done by Princeton Instruments. Should your system need repair, contact Princeton Instruments technical support for instructions (telephone, e-mail, and address information are provided on page 106 of this manual).

Use the original packing materials whenever shipping the system or system components.

Chapter 2

Installation Overview

The list and diagrams below briefly describe the sequence of actions required to hookup your system and prepare to gather data. Refer to the indicated references for more detailed information.

Action	Reference
1. If the system components have not already been unpacked, unpack them and inspect their carton(s) and the system components for in-transit damage.	Chapter 3, page 25
2. Verify that all system components have been received.	Chapter 3, page 25
3. If the components show no signs of damage, verify that the appropriate fuse has installed in the Temperature/Power Supply unit.	Chapter 3, page 26
4. Verify that the appropriate line voltage and fuses have been installed in the High Voltage (HV) power supply unit.	HV supply unit manual (IIC-100, IIC-200, IIC-300, MCP-100...).
5. If the WinView/32 software is not already installed in the host computer, install it.	WinView/32 manual
6. If the appropriate interface card is not already installed in the host computer, install it.	Chapter 3, page 30
7. Mount the camera.	Chapter 3, page 28
8. With the Temperature/Power Supply unit power turned OFF, connect the Camera-Power Supply cable to the rear of the Temperature/Power Supply unit and then to the rear of the camera. Secure the cable.	Chapter 3, page 31
9. **DANGER.** With the Temperature/Power Supply unit power and the HV supply unit turned OFF, connect the high voltage cable, provided with the system, to the Intensifier H.V.P.S connector on the HV supply and on the image intensifier housing. *Cable connections must be fully tightened down to prevent arcing.*	Chapter 3, page 32
10. On the HV supply, set the MCP Gain to **0 gain** (fully counterclockwise) and set the SHUTTER/GATE switch to **GATE**, the AUTO BRIGHT CNTRL ON/OFF switch to **OFF**, and the MCP POWER/OFF switch to **OFF**	HV supply unit manual
11. Connect the cables from the HV supply unit to the timing generator, trigger source and camera controller as appropriate to your application.	HV supply unit manual

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| Action	Reference
12. Connect the TAXI™ cable to the camera and the interface card in the host computer. Then tighten down the locking hardware.	Chapter 3, page 31
13. If the system is cooled by coolant circulation, make the tubing connections between the coolant circulator and the camera.	Chapter 4, page 34
14. Turn the Temperature/Power Supply unit ON.	
15. Turn the HV supply unit ON.	
16. Block the light coming into the camera and switch the MCP POWER /OFF switch to its MCP POWER position. The MCP Gain setting should be 0.	
17. Turn on the computer and begin running WinView/32.	WinView/32 manual
18. Enter the hardware setup information.	WinView/32 manual
19. Set the target array temperature.	Chapter 3, page 33
20. When the system reaches temperature lock, switch the SHUTTER/GATE switch (on the HV supply unit) to SHUTTER, unblock light to the camera, and begin acquiring data in focus mode.	Chapter 5
21. Adjust the MCP Gain and the focus.	Chapter 5
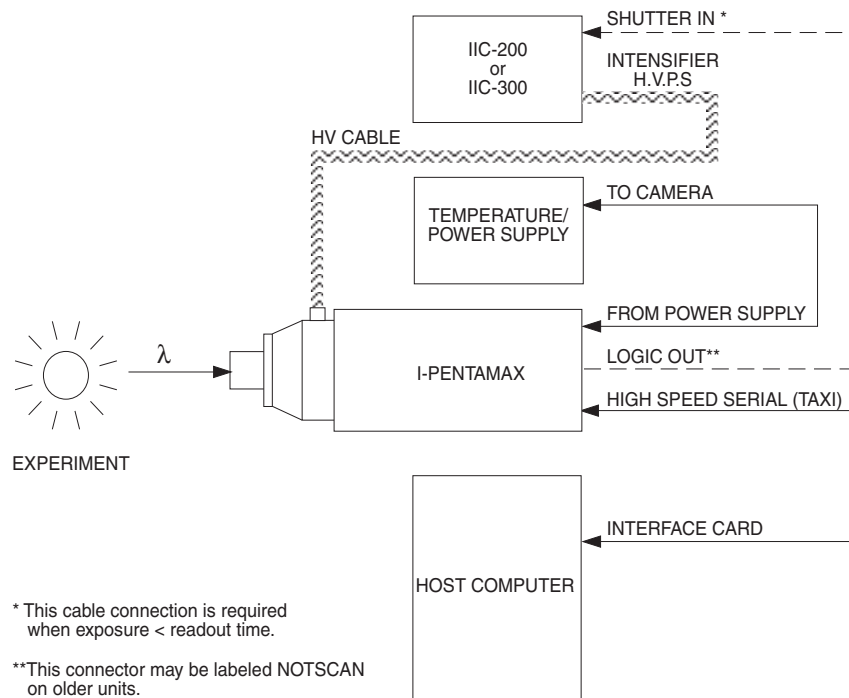
Figure 5. System Diagram: I-PentaMAX with IIC-200 or IIC-300

Chapter 3

Hardware Setup

Introduction

This chapter is provided to help you get started with your I-Penta*MAX* System. In addition to descriptions of such basics as unpacking and grounding safety, the chapter includes discussions of the requirements that have to be met before the camera can be powered. Included are environmental, power, computer, and software requirements – all essential to making successful measurements. Users are advised to read this chapter in its entirety before powering up the system. *Do not power up the system at any time while carrying out the instructions in this chapter.* Instructions for actual operation of the system under power are provided in Chapter 5, *First Light*.

WARNING! Image intensifiers can be *destroyed* if exposed to excessive light levels. Princeton Instruments cannot take responsibility for intensifier damage due to misuse.

Unpacking

During unpacking, check the system for possible signs of shipping damage. If there are any, notify Princeton Instruments and file a claim with the carrier. If damage is not apparent but system specifications cannot be achieved, internal damage may have occurred in shipment.

Checking the Equipment and Parts Inventory

The complete I-Penta*MAX* system consists of a camera, a temperature/power supply unit, a high voltage supply, several cables, a set of manuals, a computer, and computer system dependent components. Detailed information regarding cables, high voltage supplies, and computer system dependent components is provided below:

- **Camera to Power Supply cable:** 25-pin cable. Standard lengths are 10 ft (PI #6050-0184) and 15 ft (PI #6050-0228).

- **Camera to Computer cable:** 9-pin TAXI cable. Standard length is 25 ft (PI #6050-0148). Lengths up to 165 ft (50 m) are available. Optional fiber optic transducers can be used to extend this distance to as much as 2 km.

- **HV Power Supply:** Model IIC-200, IIC-100 High Voltage Power Supply, or a Princeton Instruments Pulser (FG-100, FG-100H, PG-10, or PG-200) equipped with an optional MCP-100 High Voltage Power Supply. Note that Gen II and Gen III intensifiers require different HV Power Supplies and are not interchangeable. The labels at the Intensifier H.V.P.S. connectors on the Power Supply and on the camera must be identical.

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- **Camera to High Voltage supply cable:** Normally supplied with the high-voltage power supply or pulser.

- **System Dependent Interface Components:**

  Note: An I-Penta*MAX* system requires a computer, which could be any one of several different types, each requiring a different application software package. For convenience, in discussing operating procedures, this manual refers to a PCI bus based PC running with Princeton Instruments WinView software. Nevertheless, the manual does apply as well to operation with other computers and software. Interface components as follows could be required.

  - PC Systems and PCI Power Mac™ Systems: Princeton Instruments (RSPI) High Speed Serial PCI Board: This board must be installed in the computer (computers purchased from Princeton Instruments will be shipped with the board already installed).

  - Sun Workstations: Consult the factory.

  - SGI Workstations: Consult the factory

Verifying Fuse Rating

The I-Penta*MAX* camera receives its power from the Temperature/Power Supply unit, which in turn plugs into a source of AC power and can operate from a line voltage in the range of 105-125 V or 210-250 V AC. The power requirement is 200 Watts maximum and the line frequency can range from 47 to 63 Hz. Because the Temperature/Power Supply unit senses the line voltage automatically, no action is required of the user if the line-voltage selection is changed. However, the line fuse is line-voltage dependent as indicated on the rear panel of the Temperature/Power Supply unit. Systems are ordinarily equipped with the proper fuse for the customary line voltage for the region to which they are being shipped.

Again, do not power up the system at any time while carrying out the instructions in this chapter. Instructions for actual operation of the system under power are provided in Chapter 5, *First Light*.

Table 1 shows the required fuse rating for each line voltage range. Only operate with a fuse correctly rated for the intended line voltage. If the wrong fuse is installed, the system will not be properly protected and the fuse may fail.

To verify that the installed fuse is correct:

1. Unplug the line cord from the power-input socket at the rear of the Temperature/Power Supply unit.

2. Insert a small screwdriver into the recess at the top of the Power Input assembly as shown in Figure 6 and pry open the cover.

3. Use the screwdriver to loosen the fuse carrier. Note the orientation of the arrow on the fuse carrier. Then, grasp the fuse carrier and pull it straight out of the Power Input assembly.
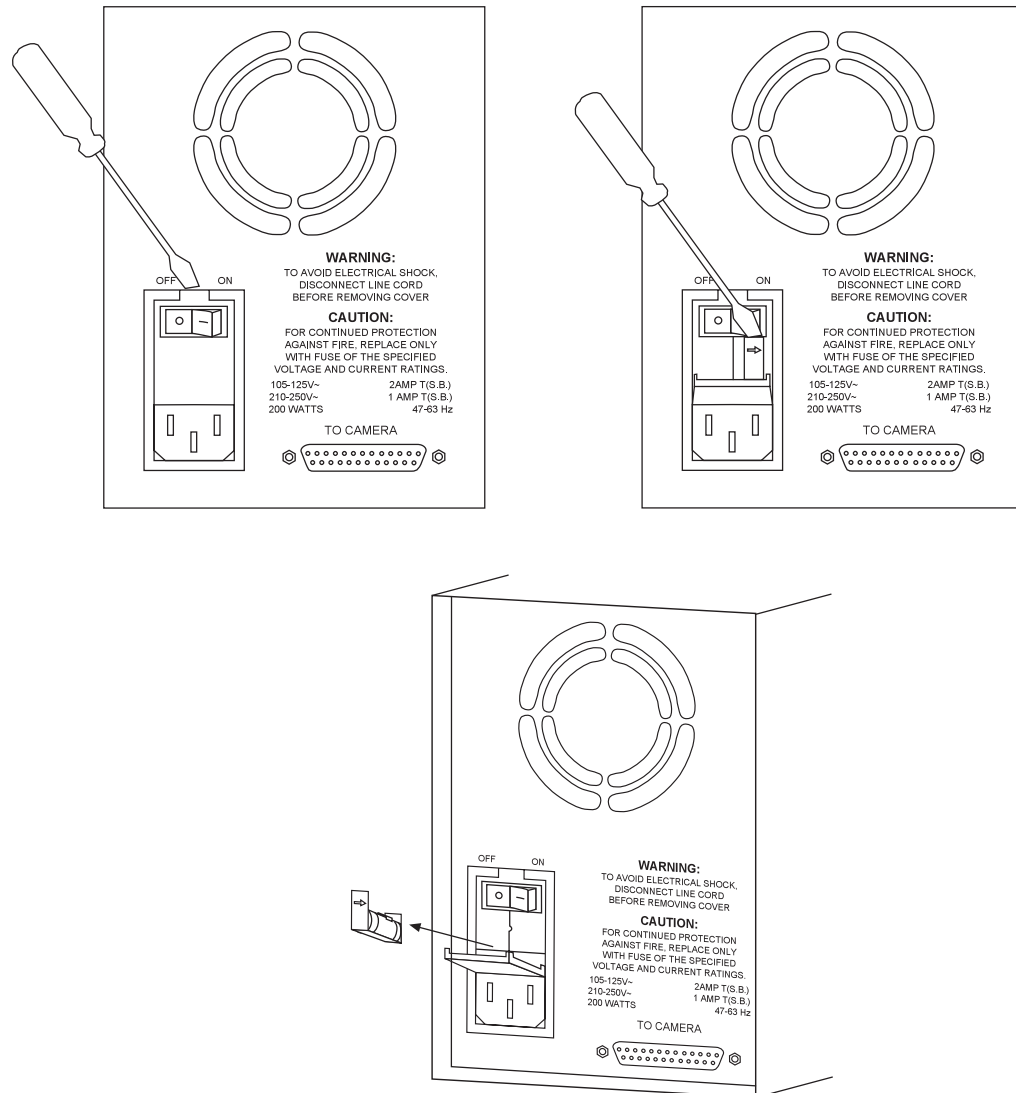
Figure 6. Power Input Assembly (Fuse Access)

4. Remove the fuse and check to be sure that its current rating is correct for the intended operating voltage. Replace the fuse if necessary.

5. After verifying that the fuse is correct, or after installing the new fuse in the carrier, should that be necessary, insert the fuse carrier into the Power Input assembly. Make sure the arrow is pointing in its original direction.

6. Return the Power Input assembly cover to its original position and snap it into place to complete the procedure.

Voltage	Fuse
105-125 V (US)	2 A slow-blow, ¼″x1¼″
210-250 V (Europe)	1 A slow-blow, ¼″x1¼″

Table 1. Voltage and Fuse Selection

Mounting the Camera

General

The I-Penta*MAX* camera can be mounted either horizontally or vertically (nose up or nose down). The camera can rest on any secure surface. Also, there is a standard ¼″ × 20 UNC thread 5/8″ deep hole on the bottom of the camera behind the lens mount for mounting versatility. When mounted horizontally, the camera should rest on a secure surface or be supported so that the mount doesn't bear the camera's weight. In many situations it may prove convenient to secure the camera with a suitable mounting bracket.

CAUTION

In the case of cameras equipped with an F-mount, do not mount the camera in the *nose-up* position without additional support. The F-mount is not designed to sustain large weights in this orientation and the camera could pull free of the lens with possible catastrophic consequences. *Contact the factory for special mounting options that enable operation in this orientation.*

If the camera should be mounted in the nose-up position beneath a table, take care to protect the mounting components from lateral stresses, such as might occur should someone accidentally bump the camera with a knee while working at the table. Two possible approaches to this problem would be to install a securely mounted bracket to the camera or to install a barrier between the camera and operator so as to prevent any accidental contact.

There are no special constraints on nose-down operation. Again, however, good operating practice might make it advisable to use a securing bracket to prevent accidental contact from unduly stressing the mounting components.

Microscopy

If the camera is going to be mounted to a microscope, the lens mounting instructions that follow will not apply. Where this is the case, users are advised to skip the following discussion and instead review Chapter 6, *Microscopy Applications.*

Mounting the Lens

If the lens mount adapter is purchased at the same time as the I-Penta*MAX*, the camera will be supplied with the adapter installed. A C-mount lens adapter is standard. Consult the factory for information about the availability of an F-mount.
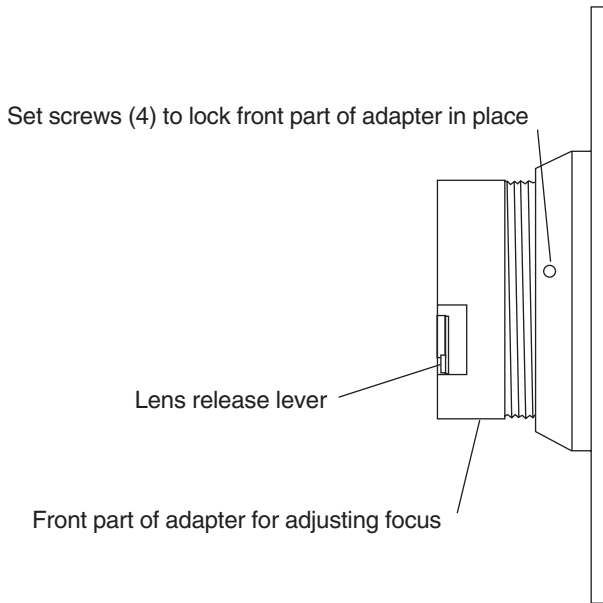
Figure 7. F-mount Lens Adapter

To install an F-mount lens on the camera:

1. Locate the large indicator dot on the side of the lens.
2. Note the corresponding dot on the front side of the camera lens mount.
3. Line up the dots and slide the lens into the mount.
4. Turn the lens counterclockwise until a click is heard, indicating that the lens is now locked in place.

To remove an F-mount lens:

1. Press the locking lever on the mount while rotating the lens clockwise until it comes free.
2. Then pull the lens straight out.

F-mount lenses typically have provision for focusing and aperture adjustment, with the details varying according the make and model of the lens. In addition, in the case of the F-mount, there is provision for adjusting the focus of the lens mount itself, if necessary, to bring the focus within range of the lens focus. This adjustment is discussed in Chapter 5.

Mounting procedures are more complex when mounting to a microscope and vary according to the make and model of the microscope as discussed in Chapter 6, *Microscopy Applications*.

Installing the Application Software

Driver Installation

Installation is performed via the WinView/32 installation process, which should be done before the interface card is installed in the host computer. On the **Select Components** dialog box (see below), click on the button appropriate for the interface card. For a Princeton Instruments (RSPI) high speed PCI card, select the **AUTO PCI** component to install the required PCI card driver. For an ISA, or no interface card, select the **Custom** component. If the interface card was installed at the factory, the appropriate driver was installed at that time.

Note: WinView/32 (versions 2.5.3 and higher) do not support the ISA interface.
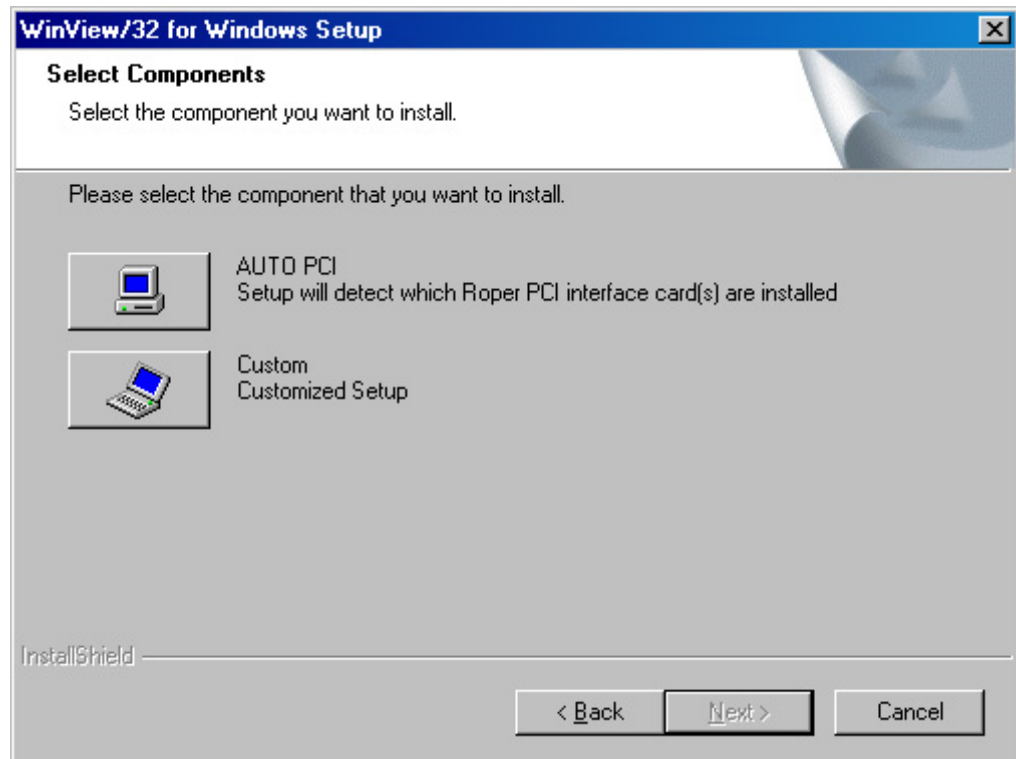
PC Interface Installation

If the computer is a PCI bus PC or Power Macintosh, it must be equipped with a Princeton Instruments (RSPI) high speed serial PCI card. Information about the installation and operation of these interface boards follows.

Note: PC computers purchased from Princeton Instruments for use in the I-Penta*MAX* system are shipped with the appropriate card already installed.

To Install a PCI Card:

CAUTION	If using WinView/32 software, either **High Speed PCI** or **PCI(Timer)** can be the selected Interface type. This selection is accessed on the **Hardware Setup|Interface** tab page. **High Speed PCI** allows data transfer to be interrupt-driven and gives the highest performance in most situations. **PCI(Timer)** allows data transfer to be controlled by a polling timer and is recommended when there are multiple devices sharing the same interrupt. However, data transfer is slower in PCI(Timer) mode and data overrun more likely. Also, PCI(Timer) cannot be used to continuously acquire small Regions of Interest in asynchronous operation.

1. Review the documentation for your computer before continuing with this installation.

2. To avoid risk of dangerous electrical shock and damage to the computer, verify that the computer power is OFF and the computer is unplugged.

3. Follow your computer manufacturer's instructions for inserting the card into an empty PCI slot.

4. After you have secured the computer cover, turn on the computer only. If an error occurs at bootup, either the PCI card was not installed properly or there is an address or interrupt conflict. Go to Chapter 10, *Troubleshooting*, page 74, for instructions.

Connecting the TAXI (Camera to Computer) Cable

To Connect the TAXI Cable:

1. Connect one end of the TAXI cable to the 9-pin port on the Interface card.

2. Tighten down the screws to lock the connector in place.

3. Connect the other end of the cable to the "High Speed Serial" port on the rear of the camera.

4. Tighten down the screws to lock the connector in place.

Connecting the Camera to Power Supply Cable

CAUTION	Turn the Temperature/Power Supply unit power OFF (OFF = 0, ON = |) before connecting or disconnecting the Camera to Power Supply cable.

To Connect the Camera to Power Supply Cable:

1. Verify that the Temperature/Power Supply unit power is OFF.

2. Connect male end of the Camera to Power Supply cable to the "To Camera" port on the rear of the Temperature/Power Supply unit.

3. Tighten down the screws to lock the connector in place.

4. Connect the female end of the cable to the "From Power Supply" port on the rear of the camera.

5. Tighten down the screws to lock the connector in place.

Connecting the Camera to HV Supply Cable

To Connect the Camera to HV Power Supply Cable:

1. Verify that the HV supply unit power is OFF and that the Temperature/Power Supply unit power is OFF.

2. At the Intensifier H.V.P.S. connector on the rear of the HV power supply, align the cable connector so the plug keyway is aligned with the socket key.

3. Gently insert the connector, taking care not force or bend the contacts.

4. Screw the connector collar onto the connector finger tight. The easiest and best method is to screw on the collar until it gets finger tight, then press the connectors together, then tighten the collar, and alternate between pressing and turning a few times.

5. Repeat Steps 2-4 for the H.V.P.S. connector on the image intensifier housing.

6. When the connectors are fully seated, they may then be fully tightened, preferably hand tight (use of a tool to tighten is acceptable as an aid, but do not exceed 10 in-lb of torque). It is necessary to tighten the connectors enough to assure the elastomer insulators in the connectors exclude air from the interface.

CAUTION

Never use any connectors or cables, other than those supplied by Princeton Instruments.

Temperature Control

Introduction

As described in Chapter 1, *Introduction*, temperature control in the I-Penta*MAX* system is quite straightforward. Typically, if the Temperature Control On/Off switch has been set to ON, it is only necessary to set the temperature display mode switch to **SET POINT** and then adjust the **TEMP SET** knob until the desired temperature is displayed. The temperature control loop will then automatically establish the desired CCD temperature. While the cool-down is in progress, the yellow **STATUS** indicator will light. When temperature lock is achieved, the yellow indicator will extinguish and the green one will light. It may prove convenient to set the temperature display mode switch to **ACTUAL** during the cool-down to observe the cooling progress.

Because the control loop is designed to achieve temperature lock as quickly as possible, overshoot will typically occur with possible toggling of the Status lights. Overshoot is particularly likely to occur if the set temperature is relatively high. This is normal behavior and should not be a cause for concern. The temperature will quickly return to the set value and permanent lock will be established. Should a low temperature be set initially and then a higher one, this overshoot would probably not occur because the temperature control loop doesn't drive the temperature higher, but rather waits passively for temperature rise to occur.

Air Cooling

An internal Peltier device directly cools the cold finger on which the CCD is mounted. The heat produced by the Peltier device is then removed by the air drawn into the camera by the internal fan and exhausted through the back-panel grill. The fan is always in operation and air cooling of both the CCD and the internal electronics takes place continuously. With air cooling alone, at an ambient temperature of 25°C, temperature lock at -20° should typically take about ten minutes. Also, if the lab is particularly warm, achieving temperature lock might take a little longer (30 minutes maximum).

Water Cooling

Supplemental water cooling can be implemented via the camera's back panel two cooling ports, either of which can be used for inflow or outflow. Connect to the ports using ¼″ inner diameter Tygon tubing secured with a suitable clamp (barb-sleeve clamps (2518-0301) are provided). *Although pressures as high as 80 psi can be applied, satisfactory cooling will ordinarily be attained with a lower pressure and moderate flow rate.* Supplemental cooling will allow temperature lock to be achieved more rapidly than would be required to attain lock at the same temperature with air cooling alone. In addition, it will be possible to achieve temperature lock at lower temperatures, typically three or four degrees lower than would be possible with air cooling alone.

CAUTION

It is essential that the cooling water ***not*** be chilled. The circulation of chilled water can cause condensation inside the camera that could cause the electronics to malfunction. ***Ordinary tap water can be too cold and should not be used!*** The water should be no colder than the laboratory ambient temperature. Closed circulation systems (such as the CC-100) that depend on ambient air cooling of the circulating water will generally give good results.

Error Conditions

The red **ERROR** indicator on the front panel of the Temperature/Power Supply will light when a temperature-control error condition is detected. At the same time, the temperature control loop will shut down *independent of the setting of the Temperature Control On/Off switch.* When this happens, the temperature will begin rising towards ambient, even though the yellow **STATUS** indicator remains lighted and *even if the error condition is corrected*. It is ***always*** necessary to cycle the power before normal temperature control operation can be re-established. Ordinarily you would turn off the power, identify and correct the error condition, and then turn the power back on and operate as usual. Refer to Chapter 10, *Troubleshooting*, for possible causes and corrective actions.

Note: The inside of the camera must reach a certain temperature before control can be re-established. You may have to wait for this to occur before regaining temperature control.

Pressurization

Before an I-Penta*MAX* leaves the factory, its front enclosure is evacuated and then backfilled with clean dry air at a pressure of nominally 1 psi. For proper operation it is essential that the integrity of the front enclosure be maintained. Do not remove the window from in front of the intensifier or loosen the pressure valve. If this enclosure should be opened to the air, the array and intensifier will be exposed to atmospheric moisture, which could condense on the array as it cools and possibly cause irreversible damage. If accidentally opened to the atmosphere, do not operate the camera. Contact Princeton Instruments Customer Support for further instructions.

WARNING!

Operating an I-Penta*MAX* that is no longer backfilled with dry air or dry nitrogen may result in condensation on the array that could cause irreversible damage. Such damage would not be covered by the Warranty.

First Light

Introduction

This chapter provides a step-by-step procedure for placing the I-Penta*MAX* system in operation for the first time. At this point a lens should be mounted on the camera (or, if necessary, the camera mounted on a microscope) and you should be ready to operate the system and proceed to viewing your first images. A suggested procedure follows. Note that the intent of this simple procedure is to help you gain basic familiarity with operation of the I-Penta*MAX* and to demonstrate that it is functioning properly. Once basic familiarity has been established, then operation with other operating configurations, ones with more complex timing modes, can be established as described in Chapter 8, *Timing Modes*. An underlying assumption of this procedure is that a video monitor is available. Although it is possible to dispense with the monitor and simply view the images on the computer monitor's screen, operations such as focusing will be somewhat easier with a video monitor because the displayed data is updated more quickly and will be as close to current as possible.

To carry out this procedure, it will be necessary to have a basic grasp of the applications software. Refer to your software manual for the required information.

WARNING!

Before You Start, if your system includes a microscope Xenon or Hg arc lamp, it is **CRITICAL** to turn off all electronics adjacent to the arc lamp, especially your digital camera system and your computer hardware (monitors included) before turning on the lamp power.

Powering up a microscope Xenon or Hg arc lamp causes a large EMF spike to be produced that can cause damage to electronics that are running in the vicinity of the lamp. We advise that you place a clear warning sign on the power button of your arc lamp reminding all workers to follow this procedure. While Princeton Instruments has taken great care to isolate its sensitive circuitry from EMF sources, we cannot guarantee that this protection will be sufficient for all EMF bursts.

Overexposure Protection

WARNING! Image intensifiers can be *destroyed* if continuously exposed to light levels higher than twice the A/D saturation level. To prevent damage to the camera, check that the following conditions are met before making any system connections.

▶ Any HV pulsers present are turned off.

▶ The **MCP POWER/OFF** switch *(do not confuse with the AC power switch.)* on the IIC-200 (IIC-300, IIC-100, or MCP-100) is set to **OFF**. *The MCP POWER/OFF switch controls the high voltage but not the IIC-200 (IIC-300, IIC-100, or MCP-100) chassis power.*

▶ The IIC-200 (IIC-300, IIC-100, or MCP-100) **SHUTTER/GATE** switch is set to **GATE**. *If there is no pulser for gating the IIC-200, IIC-300, or IIC-100, set the switch to GATE and before beginning data acquisition, set the switch to SHUTTER.*

▶ Light to the camera is *completely* blocked off.

▶ The lens aperture is set as small as possible (largest f-number).

▶ Neutral density filters are placed in front of the camera.

If the experimental conditions dictate that only a small portion of the photocathode is illuminated over relatively long periods of time, change the illuminated region of the photocathode periodically to avoid long-term localized photocathode or MCP damage.

Alarm

To reduce the risk of camera damage, an overload detection circuit in the high voltage power supply (IIC-200, IIC-100, or MCP-100) monitors the intensifier current and activates an alarm if the current exceeds the preset safety threshold. This alarm will save the intensifier if there is a light overload that is integrated over the whole intensifier. It will not protect the intensifier from damage due to small diameter light pattern overloads (as might occur with a laser).

While the alarm is sounding, the photocathode and MCP power are temporarily disabled. It is normal for the alarm to sound briefly when the high-voltage supply is first turned on. If it sounds continuously, the camera window must be immediately covered or the camera must be turned off until the illumination level is readjusted. If the alarm sounds continuously even when the illumination level is adequately low, its threshold must be internally readjusted by qualified personnel.

CAUTION Contact the factory at once if sporadic or continuous unwarranted alarms occur. They may indicate intensifier damage or another situation that requires immediate attention.

Shutter vs. Gated Operation

The I-Penta*MAX* camera has two basic operating modes, Shutter and Gated, selected by a mode switch on the IIC-200 (IIC-300, IIC-100, or MCP-100). Setting this switch to **SHUTTER** (or **CW**) selects shutter mode operation. Setting it to **GATE** selects gate mode operation.

Shutter mode defines an intensifier biasing mode. It doesn't mean or imply that the system contains a mechanical shutter. In Shutter mode operation, with no signal applied to the **SHUTTER IN** connector of the IIC-200 (IIC-300, IIC-100, or MCP-100), the intensifier is biased on continuously and the camera "sees light" for as long as the high voltage supply is turned on. For this reason, the camera is particularly vulnerable to damage from excess light in Shutter mode operation. If the **SHUTTER** TTL output (provided at the **LOGIC OUT** connector of the I-Penta*MAX* when selected by the application software) is applied to the **SHUTTER IN** connector of the IIC-200 (IIC-100 or MCP-100), the intensifier is turned ON for the programmed exposure time.

In Gated operation, the intensifier is cabled to a pulser that may have the MCP-100 high-voltage power supply option. The intensifier is biased off except during the applied pulses. *See pulser manual.* Ordinarily the duty factor is very low. The camera "sees light" only for the duration of each pulse and the risk of damage from excess light is much lower than it is in Shutter mode operation. Gated operation is analogous to shuttered operation with an unintensified camera except that the electronic gating is very much faster; the I-Penta*MAX* can be switched on or off on a nanosecond time scale. The on/off ratio is quite high, in excess of 5×10^6:1 (the exact ratio depends on the gain setting and other factors).

In both Shutter mode and Gated operation, a positive bias voltage is applied to the intensifier in the "off" state. When the intensifier is "off" the camera is practically blind.

The following procedure is intended to be done with the system in Shutter mode operation. *See the Pulser manual for additional information on operating the system in* Gated *mode.*

Procedure

1. Verify that the camera and the Power Supply are matched (i.e., the labels at the H.V.P.S connectors are identical).

2. If the system cables haven't as yet been installed, connect them as follows with the system power off.

   - Connect the 25-pin cable from the **TO CAMERA** connector on the back of the Power Supply to the **FROM POWER SUPPLY** connector on the back of the camera. Be sure to tighten the connector securing screws at both ends of the cable.

   - *With the power off*, connect the HV Supply cable to the output of the IIC-200 (IIC-100 or MCP-100). Then connect the other end to the high-voltage input of the intensifier. ***Make sure the cable connectors are tightly secured or arcing could occur that would cause CATASTROPHIC damage to the intensifier.***

DANGER | The high voltage cable carries *lethal* voltages to the image intensifier (as much as 10,000 Volts). *Never* turn on the IIC-200 (or IIC-100) high-voltage power supply or the pulser equipped with the MCP-100 modular high-voltage supply unless both ends of the high voltage cable are connected. A cable connected at one end only is not only hazardous, but is susceptible to arcing and subsequent erratic operation due to the formation of carbon tracks that may damage the intensifier.

The high voltage cable should be handled with care. Dropping the cable or banging the connectors may damage the pins, resulting in a poor or intermittent connection.

- Connect one end of the 9-pin serial cable to the **HIGH SPEED SERIAL** connector. Connect the other end to the computer interface.

   Note: If the application requires use of the optional fiber-optic data link to increase the maximum allowable distance between the Camera and the computer, the fiber-optic "pod" would be connected to the HIGH SPEED SERIAL connector with a short length of cable. Then the long distance fiber-optic cable would be connected to the pod. A similar fiber-optic pod connection is required at the computer.

- Connect a 75 Ω BNC cable from the **VIDEO** connector on the back of the camera to the video monitor's 75 Ω input. This cable must be terminated in 75 Ω. Many monitors have a switch for selecting the 75 Ω termination. *A video monitor isn't required for viewing images, but it will provide the fastest refresh rate.*

- Connect a line cord from the Power Input assembly on the back of the Temperature/Power Supply unit to a suitable source of AC power.

- With the HV Supply turned off, connect a line cord to the HV Supply and, if present, the pulser.

- **Optional**. Connect a cable from the **LOGIC OUT** connector on the back of the I-Penta*MAX* camera to the **SHUTTER IN** connector on the IIC-200 (IIC-300, IIC-100, or MCP-100), allowing exposures from 50 µs to 23 hours to be obtained.

   Note: If there is no connection to the **SHUTTER IN** connector (when operating in Shutter mode), the intensifier will be **ON** continuously.

3. If you haven't already done so, install a lens on the camera. *If the I-PentaMAX is to be operated with a microscope, see Chapter 6 and follow the directions there.* Begin with the lens capped, with a small aperture setting, and with the focus set to approximately the anticipated distance of the subject.

4. On the IIC-200 (IIC-300, IIC-100, or pulser equipped with an MCP-100):

- Set the **MCP GAIN** dial to its lowest setting. (Full counterclockwise for the IIC-200 or IIC-100).

- Set the **SHUTTER/GATE** switch to "GATE".

- Set the **AUTOBRIGHT CONTROL** (BRIGHT CONTROL) switch to "OFF".

- Set the **MCP POWER** switch to "OFF".

5. Turn on the power to the I-Penta*MAX*, the computer, and the IIC-200 (IIC-300, IIC-100, or pulser equipped with an MCP-100).

CAUTION   Do *not* turn on the **MCP POWER** switch at the IIC-200 (IIC-300, IIC-100, or MCP-100 module) yet.

The I-PentaMAX Camera power On/Off switch is located immediately above the line-cord socket on the back of the Temperature/Power Supply. As soon as the power

is turned on, the **POWER** light at the front panel of the Temperature/Power Supply unit should light.

6. Start the application software (WinView, for example).

7. At the front panel of the Temperature/Power Supply, set the temperature display mode switch to **SET POINT** and the Temperature Control **ON/OFF** switch to **ON**. As soon as this switch is set to **ON**, the yellow **STATUS** indicator should light, indicating that the temperature control loop is functioning but that temperature lock has not yet been attained.

8. Adjust the **TEMP SET** dial for a display indication of -20.0°. Then set the temperature display mode switch to **ACTUAL**. The indicated temperature should drop steadily, reaching -20° in about ten minutes (typical). At that point the yellow Status indicator will extinguish and the green one will light. Note that some overshoot is normal, which could cause the Status indicators to toggle, that is, the yellow indicator may come on again briefly. Should this happen, the displayed temperature will quickly return and stabilize at -20.0°. There may be a small difference, typically 0.1°, between the displayed set and locked temperatures. This is normal and does not indicate a system malfunction.

9. Completely block light access into the camera. Then double check the system connections.

   Note: You may want to run the camera and monitor the dark current pattern while the array is cooling down.

10. When satisfied that there are no errors, set the **MCP POWER** switch on the IIC-200 (IIC-300, IIC-100, or MCP-100 module) to the ON position. The audible intensifier alarm should sound briefly as the high voltage is applied. Verify that the MCP GAIN setting is "0": the voltage is set with the **MCP GAIN** dial.

   Notes:
   Gen II intensifiers typically function optimally with a voltage in the range of 700 V to 800 V. Gen III intensifiers typically require a higher voltage, sometimes as high as 1000 V, and a higher setting will be required. Some experimentation may be required to find the optimum setting for your intensifier.

   The MCP GAIN dial is not calibrated; however, a relative gain report is provided with the system. This report equates dial setting (from 0-100, in increments of 10) and counts/photoelectron.

   The MCP-100 **CANNOT** be used with a Gen III intensifier.

   A standard IIC-100 cannot normally be set to the higher voltage required by a Gen III intensifier. High-voltage power supplies shipped with systems having a Gen III intensifier are factory-adjusted so that they can be set to the higher voltage. If you have more than one system, take care that the intensifier and high-voltage power supplies are not interchanged.

   In the case of a PG-200 pulser equipped with an MCP-100 module, there is no way to set the MCP voltage with the system unpowered. The MCP voltage defaults to ~500 V and will need to be adjusted to the required level once the system is powered.

11. At the computer, configure the applications software for the I-PentaMAX camera. The following settings are for WinView:

Hardware Setup|Controller/CCD:

> **Controller Type:** PentaMAX
>
> **Controller Version:** version of your controller
>
> **CCD Type:** appropriate frame transfer array (EEV 512 × 512FT, for example)
>
> **Shutter Type:** Electronic
>
> **LOGIC OUT Output:** Shutter
>
> **Readout Mode:** Frame Transfer
>
> **RS170 Type:** if you are using a video monitor for focusing, select the type of monitor (NTSC or PAL).

Hardware Setup|Interface:

> **Interface Type:** High Speed PCI (or PCI(Timer))

12. Set up the applications software for **Focus** mode (continuous) operation.

13. The following settings are for WinView:

Experiment Setup|Main:

> **Exposure Time:** 0.100 sec
>
> **CCD Readout:** Use Full Chip
>
> **Accumulations:** 1

Experiment Setup|Timing:

> **Free Run:** 0.100 sec
>
> **Shutter Control:** Normal
>
> **Safe Mode**

14. Set the **SHUTTER/GATE** switch on the IIC-200 or IIC-300 to "SHUTTER".

15. Then begin data collection. Images will be sent to the monitor as quickly as they are acquired, giving as close to continuous video as is possible.

> **Note:** If you are using an external video monitor to focus the camera, you should have already selected the appropriate RS170 type in **Hardware Setup.** You will also need to select **Video Focus** from the **Acquisition** menu. The RS-170 (EIA) output should be active and the exposure time should be short (0.1 sec suggested). You will be able to adjust the display parameters and initiate acquisition from the dialog box.

16. Uncap the lens. Then adjust the lens aperture and focus for the best image as viewed on the video monitor. Some imaging tips follow.

- Begin with the lens blocked off and the MCP Gain at its lowest setting. Set the lens at the smallest possible aperture (largest f-stop number). As a guide, light barely visible to the human eye is a good starting level for Shutter mode operation. In Gate mode, higher light levels can be accommodated.

- Slowly uncover the lens. If the image becomes washed out cover the lens quickly, and reduce the light level. If the image is dim, increase the MCP Gain setting.

- Increase gain to about 1/2 maximum on the dial or the PG-200.

- Adjust the lens aperture until a suitable value is found. Check the brightest regions of the image to determine if the A/D converter is at full-scale. Adjust the aperture just slightly smaller (higher f-stop) than the setting where maximum brightness on any part of the image occurs.

  Note: Long-term imaging of bright objects at low gain may cause image "burn-in" or memory. This is especially true for Gen III intensifiers. Long-term viewing of bright objects is not recommended for intensified cameras.

- Place a suitable target in front of the lens. Objects with text or graphics work best. The target should be located at infinity (at least 1000 focal lengths from the lens). If working with a microscope, use any easily viewed specimen. It is generally not advisable to attempt fluorescence imaging during this phase of operation.

- Set the focus adjustment of the lens for maximum sharpness in the viewed image.

- Note that the camera's F-mount adapter, if present, also has a factory-set focus adjustment. *If necessary,* this focus can be changed to bring the image into range of the lens focus adjustment. The following procedure could also be used for a C-mount adapter and lens. To change the focus setting:

  - Reduce the light and/or exposure to allow the operating lens iris to maximum or near maximum aperture without overloading the camera.

  - While using a large aperture, set the focus setting of the lens to infinity.

  - Loosen the lens mount set screws with a 0.050″ Allen wrench.

  - While observing the image at the computer or video monitor, rotate the lens and the adapter as a unit until the sharpest possible focus is obtained. Tighten the setscrews. All focusing may now be done with the focus adjustment on the lens.
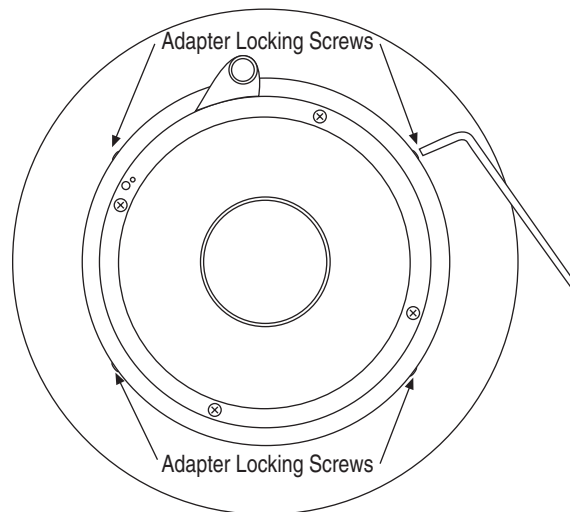

Figure 8. F-mount Adapter Focus Adjustment

This completes the basic familiarization and checkout procedure. Some additional comments on imaging follow.

Imaging Field of View

When used for two-dimensional imaging applications, the I-Penta*MAX* camera closely imitates a standard 35 mm camera. Since the CCD is not the same size as the film plane of a 35 mm camera, the field of view at a given distance is somewhat different.
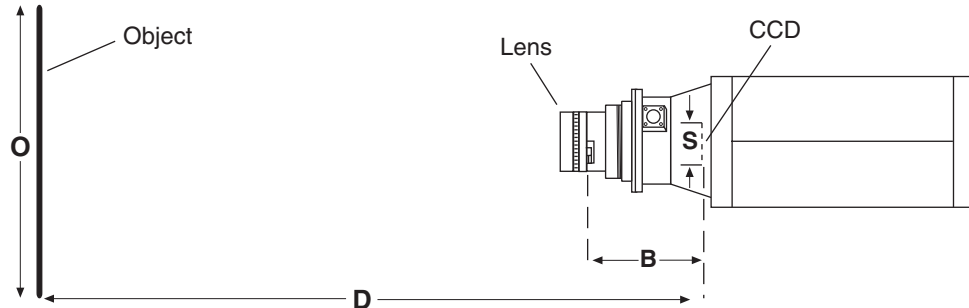

Figure 9. Imaging Field of View

D = distance between the object and the CCD

B = 17.5 mm for C-mount; 46.5 mm for F-mount

F = focal length of lens

S = CCD horizontal or vertical dimension

O = horizontal or vertical field of view covered at a distance D

M = magnification

The field of view is:

$$O \ = \ S/M, \ \ \text{where} \ \ M = \frac{FD}{(D - B)^2}$$

This completes *First Light*. If the system functioned as described, you can be reasonably sure it has arrived in good working order. Other topics, which could be quite important in certain situations, are discussed in the following chapters. See the appropriate application software manual for information on using the software to control the system.

Microscopy Applications

Introduction

This chapter discusses the setup and optimization of your digital imaging system as applied to microscopy.

Since scientific grade cooled imaging systems are usually employed for low light level microscopy, the major goal is to maximize the light throughput to the camera. In order to do this, the highest Numerical Aperture (NA) objectives of the desired magnification should be used. In addition, you should carefully consider the transmission efficiency of the objective for the excitation and emission wavelengths of any fluorescent probes employed. Another way to help maximize the transmission of light is to choose the camera port that uses the fewest optical surfaces in the pathway, since each surface results in a small loss in light throughput. Often the trinocular mount on the upright microscope or the bottom port on the inverted microscope provide the highest light throughput. Check with the manufacturer of your microscope to determine the optimal path for your experiment type.

A rule of thumb employed in live cell fluorescence microscopy is "if you can see the fluorescence by eye, then the illumination intensity is too high". While this may not be universally applicable, it is a reasonable goal to aim for. In doing this, the properties of the CCD in your camera should also be considered in the design of your experiments.

Hardware binning can also be used to increase sensitivity. If sufficient detail will be preserved, you can use 2×2 binning (or higher) to increase the light collected at each "super-pixel" by a factor of four or more. This will allow the user to reduce exposure times, increasing temporal resolution and reducing photodamage to the living specimen.

Another method to minimize photodamage to biological preparations is to synchronize a shutter on the excitation pathway to the exposure period of the camera. This will limit exposure of the sample to the potentially damaging effects of the excitation light.

Mounting the Camera on the Microscope

The camera is connected to the microscope via a standard type mount coupled to a microscope-specific adapter piece. There are two basic camera-mounting designs: the C-mount and the F-mount. The C-mount employs a standard size thread to connect to the adapter while the F-mount uses a tongue and groove type mechanism to align the camera with an adapter. Either or both types could be available for a specific camera model.

C-Mount

For a camera equipped with a C-mount thread, use a standard C-mount adapter supplied by the microscope manufacturer to attach the camera to the microscope. *If you don't have an adapter, you can obtain one through your microscope distributor.*

The adapter can be screwed into the camera and then the assembly can be secured to the microscope using the standard set screws on the microscope. The camera can be mounted on the trinocular output port, the side port or the bottom port of the inverted microscope. When mounting the camera perpendicular to the microscope on the side port, we recommend that you provide some additional support for your camera to reduce the possibility of vibrations or excessive stress on the C-mount nose. For the bottom port of the inverted microscope, the C-mount is designed to support the full weight of the camera, however, you may wish to provide some additional support for the camera since the camera is in a position where it could be deflected by the operator's knee or foot. This kind of lateral force could damage the alignment of the nose and result in sub-optimal imaging conditions.

Most output ports of the microscope do not require additional optical elements to collect an image, however, please check with your microscope manual to determine if the chosen output port requires any relay lens. In addition, all optical surfaces should be free from dust and fingerprints, since these will appear as blurry regions or spots and hence degrade the image quality.

F-Mount

For a camera with the F-mount type design, you will need two elements to mount the camera on your microscope. The first element is a Relay Lens. This lens is usually a 1× relay lens that performs no magnification. Alternatively, you may use a 0.6× relay lens to partially demagnify the image and to increase the field of view. There is also a 2× relay lens available for additional magnification. The second element is a microscope-specific Bottom Clamp. Table 2 shows which bottom clamps are routinely used with each of the microscope types. They are illustrated in Figure 10. If you feel that you have received the wrong type of clamp, or if you need a clamp for a microscope other than those listed, please contact Princeton Instruments.

Microscope Type	Bottom Clamp Type
Leica DMR	L-clamp
Leitz All types	NLW-clamp
Nikon Optiphot, Diaphot, Eclipse	O-clamp
Olympus BH-2, B-MAX, IMT-2	V-clamp
Zeiss Axioscope, Axioplan, Axioplan 2, Axiophot	Z-clamp
Zeiss Axiovert	ZN-clamp

Table 2. Bottom Clamps for Different Type Microscopes

To assemble the pieces, first pick up the camera and look for the black dot on the front surface. Match this dot with the red dot on the side of the relay lens. Then engage the two surfaces and rotate them until the F-mount is secured as evidenced by a soft clicking sound. Now, place the long tube of the relay lens into the bottom clamp for your microscope, securing the two together with the three setscrews at the top of the clamp as shown in Figure 10.

This whole assembly can now be placed on the microscope, using the appropriate setscrews on the microscope to secure the bottom clamp to the output port of the microscope.

The F-mount is appropriate for any trinocular output port or any side port. When mounting the camera perpendicular to the microscope on the side port, we recommend that you provide some additional support for your camera to reduce the possibility of vibrations or excessive stress on the F-mount nose. Princeton Instruments *does not* advise using an F-mount to secure the camera to a bottom port of an inverted microscope due to possible failure of the locking mechanism of the F-mount. *Contact the factory for information about a special adapter for operating in this configuration.*
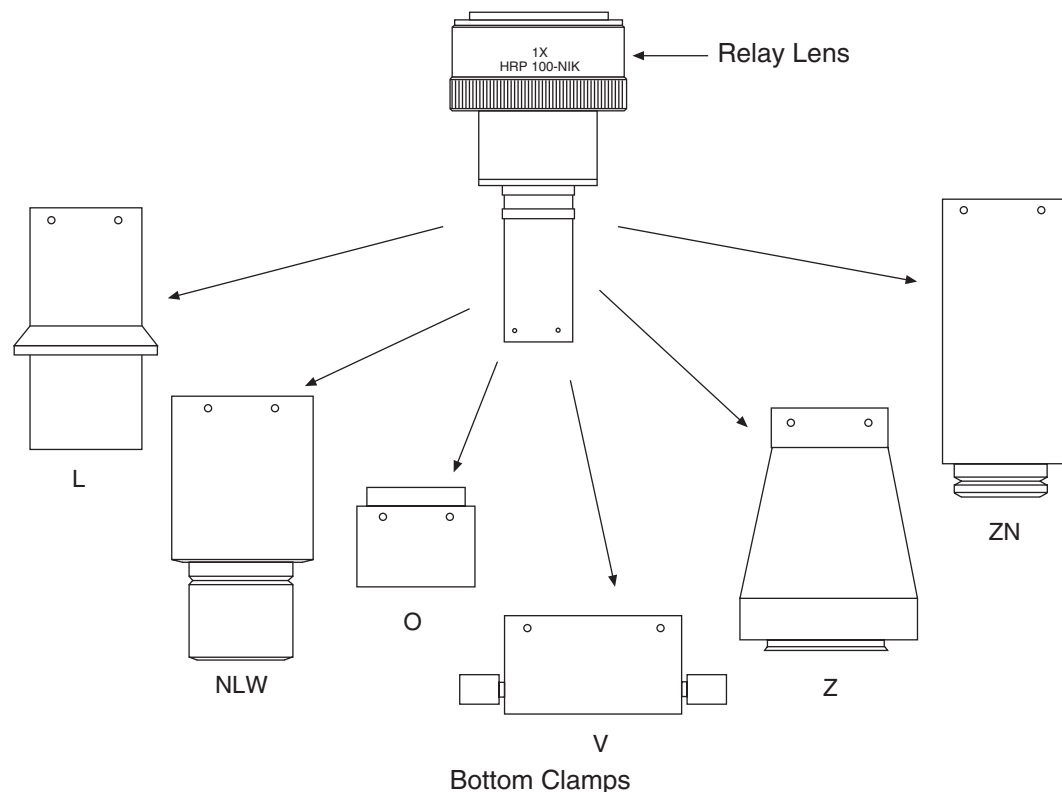
Figure 10. F-mount Adapters
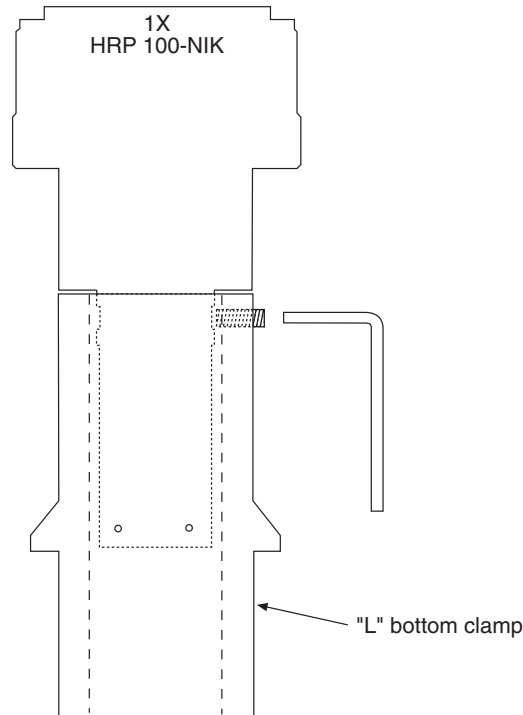
Figure 11. Bottom Clamp secured to Relay Lens

Operation

Xenon or Mercury Arc Lamp Precautions

WARNING!

> **Before You Start**, if your system includes a microscope Xenon or Hg arc lamp, it is **CRITICAL** to turn off all electronics adjacent to the arc lamp, especially your digital camera system and your computer hardware (monitors also) before turning on the lamp power.

Powering up your microscope Xenon or Hg lamp causes a large EMF spike to be generated that can cause damage to electronics that are running in the vicinity of the lamp. We advise that you place a clear warning sign on the power button for your arc lamp reminding all workers to follow this procedure. While Princeton Instruments has taken great care to isolate its sensitive circuitry from EMF sources, we cannot guarantee that this protection will be sufficient for all EMF bursts.

Focusing the Microscope

1. Direct all of the light to the eyepieces

2. Focus on the target, set up Koehler illumination and adjust the condenser to match the objective, all in the transmitted light mode (as per the instructions provided by your microscope manufacturer).

3. Decrease the transmitted light intensity to a level that is low, but still sufficient to allow visualization by eye.

4. Redirect the light to the camera port.

Adjusting the Parfocality of the Camera

On a C-mount system, the camera should be very close to parfocal, although some C-mounts will be adjustable using set screws on the microscope to secure the adapter slightly higher or lower in position.

To adjust the parfocality on an F-mount system, begin collecting images with a short exposure time and focus the light on the camera by rotating the ring on the Relay Lens without touching the main focusing knobs on the microscope.

While adjusting parfocality, you will need to acquire images rapidly to minimize the delay between the time a setting is changed and the time when the effect of the change can be observed. The specifics of how to proceed will vary according to the application software.

In WinView, select **Acquisition**, **Focus**. Begin with an exposure time 0.1 sec. Then use RUN to begin data acquisition and STOP to end it when you are finished focusing. *See your WinView manual for additional information.*

Many Princeton Instruments cameras, both C-mount and F-mount, also make provision for extending the focus range by providing a focus adjustment on the camera lens mount. If necessary, this focus can be changed to bring the image into range of the relay lens or other microscope focus adjustment as described on page 41.

Imaging Hints

Determine the gray levels of the image by placing the cursor within the image and monitoring the values shown. For optimal image quality of a 12-bit image, the highest value in the field should be over 3000 counts but less than 4095 (which is saturating). You may increase the number of counts by increasing your exposure or by increasing the amount of light illuminating the specimen.

Fluorescence

Once you have acquired a suitable image in transmitted light mode, you may switch to fluorescence mode.

In fluorescence mode you generally want to minimize the bleaching of your sample, usually achieved by placing several neutral density filters in the excitation pathway to minimize the illumination intensity. There will always be a trade-off here; when you maximize signal quality by increasing the illumination intensity, you need to consider whether your preparation can tolerate these conditions. In general, it is better to expose longer with a lower intensity than to expose for a shorter time with a higher intensity; nevertheless, your experimental conditions will dictate which path you take.

In fluorescence measurements you may not wish to maximize the gray levels in the image, since this may cause bleaching of the dye or photodamage to the cell. Maintain the minimum exposure required to get a sufficiently high quality image.

If the scaling on the image does not appear good to the eye, you may use additional scaling features available in the software. See your software manual for information on how to properly use the contrast enhancing features of the program.

Microscopes and Infrared Light

Microscope optics have very high transmission efficiencies in the infrared region of the spectrum. Since the light sources are very good emitters in the infrared, some microscopes are equipped with IR blockers or heat filters to prevent heating of optical elements or the sample.

For those microscopes that do not have the better IR blockers, the throughput of infrared light to the camera can be fairly high. In addition, while the eye is unable to see the light, the camera is very efficient in detecting near-infrared wavelengths. As a result, the contaminating infrared light will cause a degradation of the image quality due to a high background signal that will be invisible to the eye. Therefore, it is recommended that you add an IR blocker prior to the camera if you encounter this problem with the microscope.

Intensifier

Overview of Intensifier Operation

The modern image intensifier results from a concerted effort undertaken to develop night vision capabilities for military applications and to this day the primary application remains night vision – the ability to see in low light level conditions. Basically, an intensifier is a four-electrode vacuum-tube device having a photocathode (at the input), a microchannel plate (for increased gain), and a phosphor screen (at the output). There are two types of intensifiers: inverter and proximity focused. The inverter type electrostatically focuses and inverts the image inside the tube. The proximity-focused type has all of the elements closely spaced, has no need for focus electrodes, and is much more compact. I-PentaMAX has a proximity focused type intensifier that is fiberoptically coupled to the CCD (1.5:1 taper ratio).

Figure 12 shows a schematic of an image intensifier tube. Photons admitted to the tube strike the photocathode, which then emits photoelectrons in response. The electrons are accelerated across a half millimeter gap by an acceleration potential to the microchannel plate (MCP). When an electron enters the microchannel, it gets amplified by the voltage difference between the front and back surfaces of the microchannel plate. The electron becomes an electron packet as it travels down the channel. When the electron packet exits the rear of the microchannel, it is pulled across a small gap to a phosphor screen by a proximity focusing voltage of approximately 5 kV. There, the kinetic energy of that electron packet is converted into visible photons by the phosphor. The photons in turn exit the tube via the fiber-optic stub and strike the CCD array.
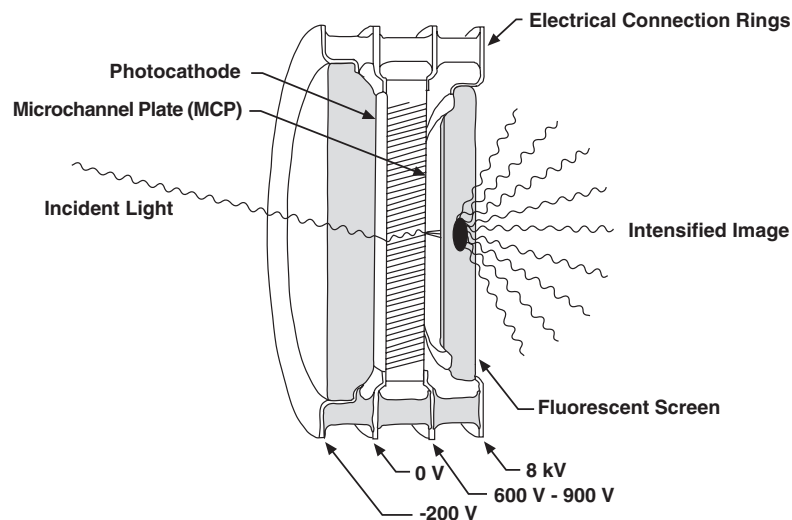

Figure 12. Image Intensifier Tube

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Figure 13 illustrates microchannel operation. The channels function in much the same manner as the dynode stage in a photomultiplier tube through the use of a secondary emitter. Each time the electron strikes the wall of the tube, it strikes a secondary emitter, which causes a shower of electrons. The process is driven by the potential difference between the front and back surface of the microchannel plate. The higher the potential, the greater the electron gain will be. Normally the tubes are operated somewhere in the range of 500 V to 900 V, which results in an electron-gain in the range of 10^3 to 10^5 electrons. For the I-Penta*MAX*, this voltage is set via the MCP GAIN dial on the IIC-200 (IIC-300, IIC-100, or MCP-100).
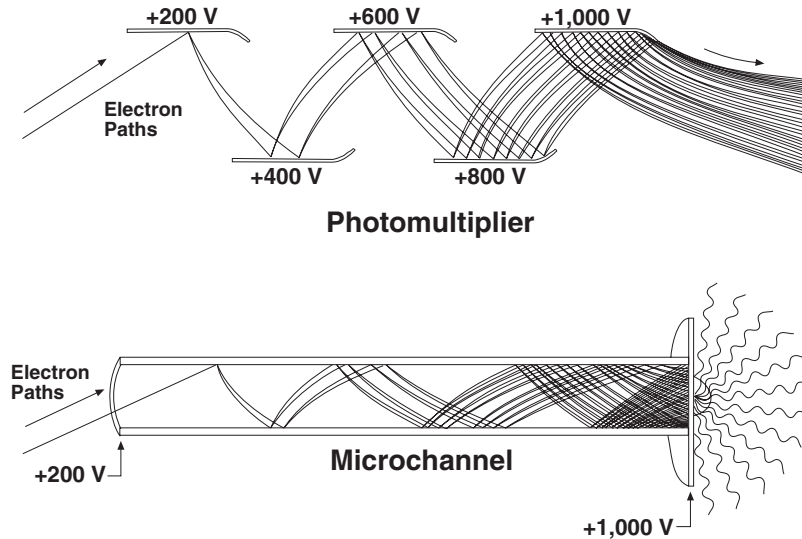
Figure 13. Microchannel Plate Operation

Intensifier Alarm

To reduce the risk of camera damage, an overload detection circuit in the IIC-200 (IIC-300, IIC-100, or MCP-100) high voltage power supply monitors the intensifier current and activates an alarm if the current exceeds the preset safety threshold. While the alarm is sounding, the photocathode and MCP power are temporarily disabled. It is normal for the alarm to sound briefly when the high-voltage supply is first turned on. If it sounds continuously, the camera window must be immediately covered or the camera must be turned off until the illumination level is readjusted. If the alarm sounds continuously even when the illumination level is adequately low, its threshold must be internally readjusted by qualified personnel.

Note: This alarm protects against damage due to light flooding the intensifier, but it will not protect against spot damage caused by small diameter light overloads.

CAUTION   Contact the factory at once if sporadic or continuous unwarranted alarms occur. They may indicate intensifier damage or another situation that requires immediate attention.

Timing Modes

The Princeton Instruments I-Penta*MAX* system has been designed to allow the greatest possible flexibility when synchronizing data collection with an experiment.

The chart below lists the timing mode combinations. Use this chart in combination with the detailed descriptions in this chapter to determine the optimal timing configuration.

Mode	Shutter
Freerun	Normal
External Sync	Normal
External Sync	Preopen
Continuous Cleans	Normal
Continuous Cleans	Preopen

Table 3. Camera Timing Modes

Notes:

In the following discussions of the timing modes and in the associated timing diagrams, there are many mentions of the shutter. Although the I-Penta*MAX* doesn't have a shutter, these discussions and diagrams are nevertheless valid. The intensifier controls exposure in an intensified camera in much the same way as a mechanical shutter does in an unintensified shutter. In shutter mode operation (as selected at the high-voltage power supply), the **SHUTTER** signal provided at the **LOGIC OUT** connector (if selected by the software) can be used to control the high-voltage power supply and thus the exposure. The references to a mechanical shutter that occur in the following discussions and diagrams can be interpreted as references to the **SHUTTER** signal. In gated mode operation, the gate pulses generated by the pulser control the high-voltage supply and hence the exposure. The **SHUTTER** signal is also used in gated operation, but for a different purpose, namely, to inhibit the pulser during readout of the CCD.

Another timing consideration to keep in mind is that the following discussions treat frame-transfer operation as a special timing mode. Because the I-Penta*MAX* is only sold with a frame-transfer CCD, users might reasonably conclude that the discussions of "standard" and "full-frame" timing don't apply. This is not the case. In gated operation the CCD is usually operated full-frame to prevent gate pulses from being applied while reading the data. The frame rate is reduced and the timing is as shown in Figure 16.

Full Speed (sync) or Safe Mode (async)

Selection of Full Speed (formerly known as Synchronous mode) or Safe Mode (formerly known as Asynchronous mode) determines the overall control of experiment timing. In Full Speed mode, the I-Penta*MAX* runs according to the timing of the experiment, with no interruptions from the computer. In Safe Mode, the computer processes each frame as it is received and the I-Penta*MAX* cannot collect the next frame until the previous frame has been completely processed. Flow charts for both modes of operation are shown in Figure 14 on the next page.

Full Speed mode is primarily for collection of back-to-back experimental data, where timing is critical and events cannot be missed. Once the I-Penta*MAX* is sent the Start Acquisition command (STARTACQ) from the computer, all frames are collected without further intervention from the computer. The advantage of this timing mode is that timing is controlled completely through hardware. A drawback to this mode is that the computer will only display frames when it is not performing other tasks. Image display has a lower priority, so the image on the screen may lag several images behind. *A video monitor connected to the VIDEO output will always display the current image.* A second drawback is that a data overrun may occur if the number of images collected exceeds the amount of allocated RAM or if the computer cannot keep up with the data rate.

Safe Mode is primarily useful for experiment setup, including alignment and focusing, when it is necessary to have the most current image displayed on the screen. It is also useful when data collection must be coordinated with external devices such as external shutters and filter wheels, or when data collection is part of a macro. As seen in Figure 14, in the Safe Mode the computer controls when each frame is taken. After each frame is received, the camera sends the Stop Acquisition command (STOPACQ) to the camera, instructing it to stop acquisition. Once that frame is completely processed and displayed, a STARTACQ is sent from the computer to the camera, allowing it to take the next frame. Display is therefore, at most, only one frame behind the actual data collection.

One disadvantage of the Safe Mode is that events may be missed during the experiment, since the I-Penta*MAX* is disabled for a short time after each frame. The time delay between each frame acquisition is no longer fixed since the software, which has significantly more jitter than the hardware, has full control of data collection.

Standard Timing Modes

The basic I-Penta*MAX* timing modes are Freerun, External Sync, and Software Trigger. These timing modes are combined with the Shutter options to provide the widest variety of timing modes for precision experiment synchronization.

The shutter options available include Normal, Preopen, Disable Opened or Disable Closed. Disable simply means that the shutter will not operate during the experiment. Disable closed is useful for making dark charge measurements, or when no shutter is present in the system. Preopen, available in the External Sync mode, opens the shutter as soon as the I-Penta*MAX* is ready to receive an External Sync pulse. This is required if the
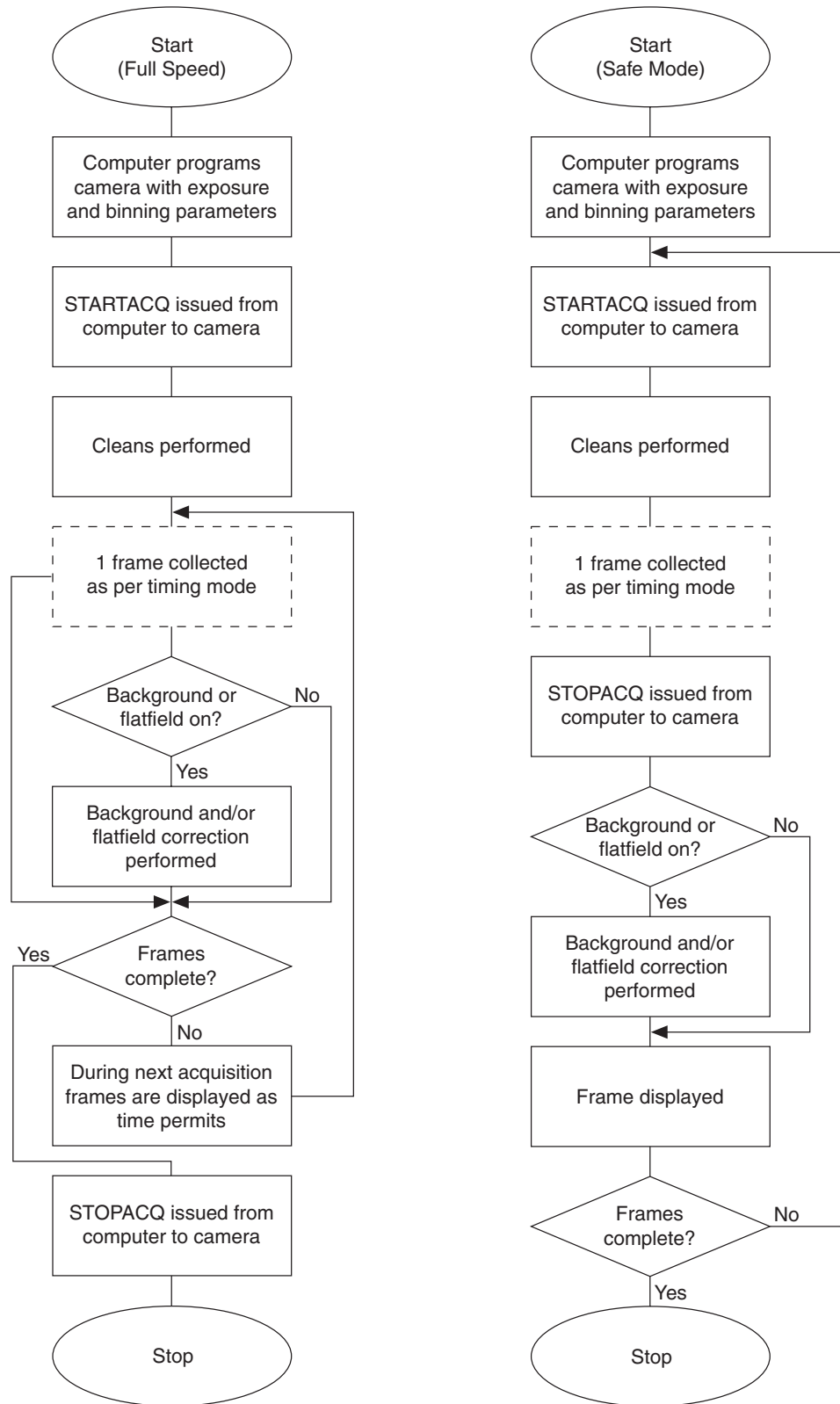
**Start
(Full Speed)**

Computer programs
camera with exposure
and binning parameters

STARTACQ issued from
computer to camera

Cleans performed

1 frame collected
as per timing mode

Background or
flatfield on?   No

Yes

Background and/or
flatfield correction
performed

Frames
complete?

Yes

No

During next acquisition
frames are displayed as
time permits

STOPACQ issued from
computer to camera

Stop

**Start
(Safe Mode)**

Computer programs
camera with exposure
and binning parameters

STARTACQ issued from
computer to camera

Cleans performed

1 frame collected
as per timing mode

STOPACQ issued from
computer to camera

Background or
flatfield on?   No

Yes

Background and/or
flatfield correction
performed

Frame displayed

Frames
complete?   No

Yes

Stop

Figure 14. Chart of Full Speed and Safe Mode Operation

time between the External Sync pulse and the event is less than a few milliseconds, the time it takes the shutter to open.

The shutter timing is shown in the timing diagrams that follow. Except for Freerun, where the modes of shutter operation are identical, both Normal and Preopen lines are shown in the timing diagrams and flow chart.

The timing diagrams are labeled indicating the exposure time (t_{exp}), shutter compensation time (t_c), and readout time (t_R). These parameters are discussed in more detail in Chapter 9.

Freerun Timing

In the Freerun mode the controller does not synchronize with the experiment in any way. The shutter opens as soon as the previous readout is complete, and remains open for the exposure time, t_{exp}. Any External Sync signals are ignored. This mode is useful for experiments with a constant light source, such as a CW laser or a DC lamp. Other experiments that can utilize this mode are high repetition studies, where the number of shots that occur during a single shutter cycle is so large that it appears to be continuous illumination.
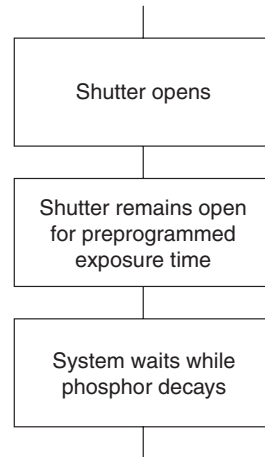
Figure 15. Freerun Timing chart
(part of the chart in Figure 14)

Other experimental equipment can be synchronized to the I-Penta*MAX* system by using the NOTSCAN signal, one of the software programmable outputs available at the **LOGIC OUT** connector. This TTL output for Full Speed operation is shown in Figure 16.
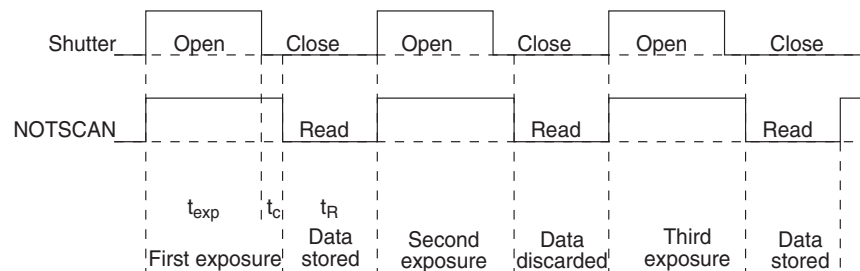
Figure 16. Freerun Timing diagram

External Sync Timing

In this mode all exposures are synchronized to an external source. As shown in the flow chart, Figure 17, this mode can be used in combination with Normal or Preopen Shutter operation and with Continuous Cleans.

In Normal Shutter mode, the controller waits for an External Sync pulse, then opens the shutter for the programmed exposure period (see Figure 17). As soon as the exposure is complete the shutter closes (shutter compensation time is discussed in Chapter 9) and the CCD array is read out. The shutter requires 5-10 msec to open completely, depending on the model of shutter. Because of this shutter opening delay, the External Sync pulse provided by the experiment must precede the actual signal by at least that much time. If not, the shutter will not be open during the entire signal, or the signal may be missed completely. Also, since the amount of time from the initialization of the experiment to the first External Sync pulse is not fixed, an accurate background subtraction may not be possible for the first readout. In multiple-shot experiments this is easily overcome by simply discarding the first frame. Alternatively, Normal Shutter mode can be run with Continuous Cleans active: this will remove any charge (ambient light and dark charge) that would otherwise accumulate on the array during the wait time (t_w).

In the Preopen Shutter mode, shutter operation is only partially synchronized to the experiment (see Figure 17). As soon as the controller is ready to collect data the shutter opens. Upon arrival of the first External Sync pulse at the I-Penta*MAX*, the shutter remains open for the specified exposure period, closes, and the CCD is read out. As soon as readout is complete the shutter reopens and waits for the next frame. The Preopen mode is useful in cases where an External Sync pulse cannot be provided 5-10 msec before the actual signal occurs. Its main drawback is that the CCD is exposed to any ambient light while the shutter is open between frames. If this ambient light is constant, and the triggers occur at regular intervals, this background can also be subtracted, providing that it does not saturate the CCD, but accurate background subtraction may not be possible for the first frame. Instead of using background subtraction, you could run Preopen Shutter mode with Continuous Cleans active: this will remove any charge (ambient light and dark charge) that would otherwise accumulate on the array during the wait time (t_w).

As mentioned above, Continuous Cleans can be selected for External Sync timing and will remove any charge from the array until the moment the External Sync pulse is received (see Figure 18). This cleaning is in addition to the standard "cleaning" of the array, which occurs after the controller is enabled. Once the External Sync pulse is received, cleaning of the array stops as soon as the current row is shifted, and frame collection begins. With Normal Shutter operation the shutter is opened for the set exposure time. With PreOpen Shutter operation, the shutter is open during the continuous cleaning and, once the External Sync pulse is received, the shutter remains open for the set exposure time and then closes. If the vertical rows are shifted midway when the External Sync pulse arrives, the pulse is saved until the row shifting is completed, to prevent the CCD from getting "out of step." As expected, the response latency is on the order of one vertical shift time, from 1-30 µsec depending on the array. This latency does not prevent the incoming signal from being detected, since photogenerated 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. Note that the NOTSCAN signal is active while the camera is

cleaning, generating pulses with a frequency equal to the vertical shift time of the device being used. This characteristic makes NOTSCAN unsuitable for inhibiting a pulser while the array is being read out. Use the SHUTTER signal instead (NOTSCAN and SHUTTER can also be provided at the I-Penta*MAX* **LOGIC OUT** connector).
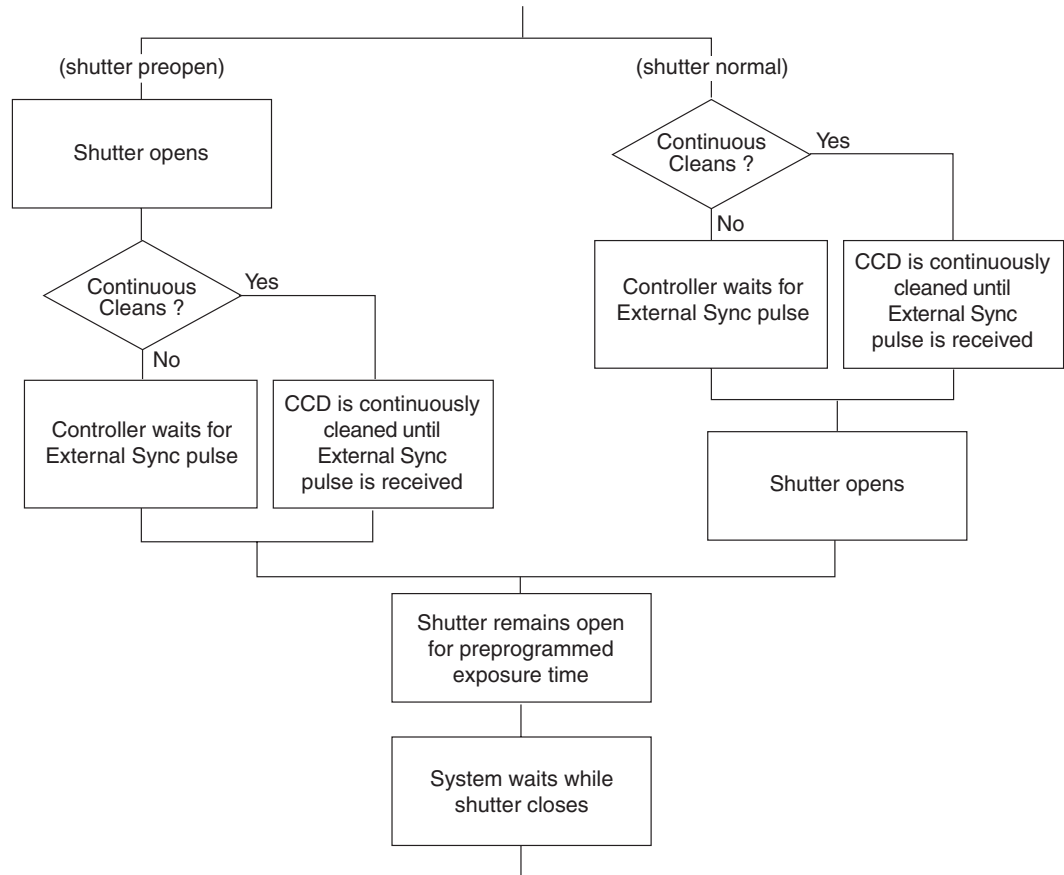

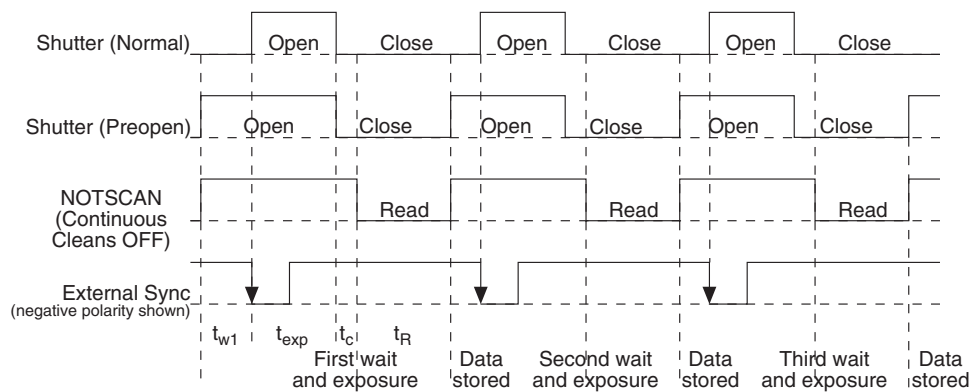*Figure 17.   Chart showing two External Sync Timing Options*

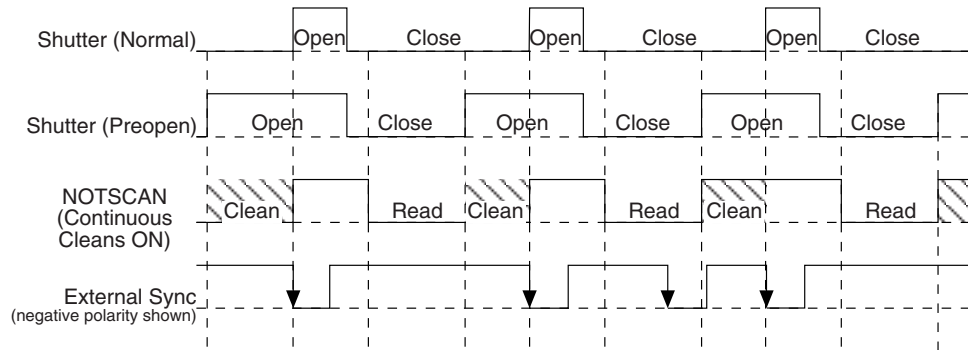*Figure 18.   External Sync (Continuous Cleans OFF) Timing diagram*

Figure 19. External Sync (Continuous Cleans ON) Timing diagram

Software Trigger

The third timing mode available with the I-Penta*MAX* camera is called Software Trigger. If Software Trigger is the selected mode, clicking on the **Acquire** button will initiate back-to-back collection of the requested number of images without further TTL trigger input.

Frame Transfer Mode

For frame transfer operation half the CCD is used for sensing light, and the other half for storage and readout. Not all CCD arrays are capable of readout in this mode, as it requires that charge be shifted independently in the two halves of the array. *See Chapter 9 for a detailed discussion of readout in the frame-transfer mode operation; the primary focus of this section is frame-transfer timing.*

There timing modes available in frame transfer mode are similar to their counterparts in full frame (standard) operation, except that in frame transfer operation a shutter is not generally used. Because there is no shutter (or the shutter is only closed after the camera has collected a series of frames), shutter Normal, Preopen, or Disable have no physical meaning here. The exposure half of the array sees light continuously if no shutter is present. The *actual exposure time* is the time between charge transfers from the exposure half of the array to the storage half of the array, and may be longer than the programmed exposure, t_{exp}. Charge transfer from the exposure half of the array to the storage half occurs very quickly at the start of each read. During the read, the stored charge is shifted to the array's output port, the same as in standard operation.

In Freerun Frame-Transfer mode operation, half the array is exposed for the set exposure time (t_{exp}), then quickly shifts the charge into the other half of the array. As soon as this shifting is complete the next exposure immediately begins. During the exposure, charge is read out of the storage half of the array.

In External Sync - Frame Transfer mode operation, the camera reads out one frame for every External Sync pulse received, providing that the frequency does not exceed the maximum rate possible with the system. As shown in Figure 20, the first readout is discarded, since these data are already in the storage half of the array when the first External Sync pulse was received and thus contain no information. From the second frame on, every frame is digitized and stored. Without a shutter, the exposure time is always set by the sync signal frequency, as long as the frequency of the sync signal is

less than one divided by the scan time. The minimum exposure time is equal to the amount of time needed to read out the storage half of the array, unless an external shutter is used. Figure 20 shows an example where $t_{exp} + t_{w1} + t_c < t_R$. t_{w1} is the time the controller waits for the first pulse.
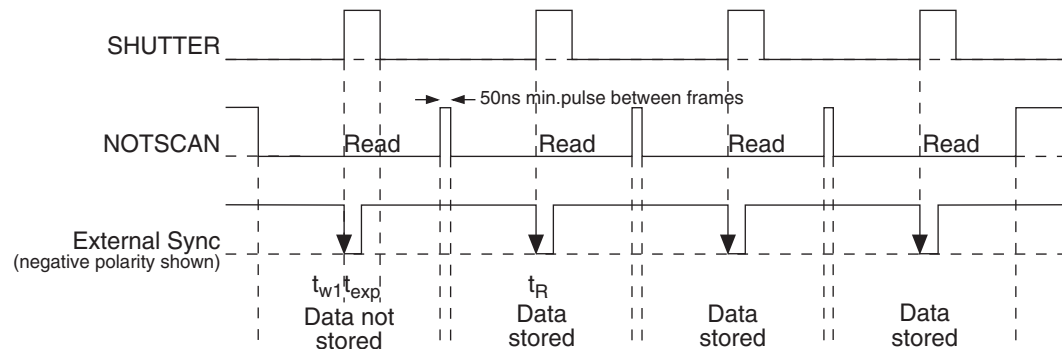

Figure 20. Frame Transfer where $t_{exp} + t_{w1} + t_c < t_R$.

Although in Figure 20 and Figure 21, SHUTTER, one of the software programmable outputs available at the **LOGIC OUT** connector, is low before the External Sync pulse is received, remember that in most cases there is no mechanical shutter present, so light falls on the array during the entire readout. Figure 21 shows the timing of the experiment if the exposure time is set to a value greater than the readout time ($t_{exp} + t_{w1} + t_c > t_R$).

The presence of an electronic shutter in frame-transfer systems allows exposure times that are less than the readout time of the device to be achieved. The frame rates of frame-transfer devices are much higher than full-frame CCDs of comparable resolution. The high speed of the electronic shutter allows the camera to operate in frame transfer mode with very little time taken in exposure if flash illumination is used. .
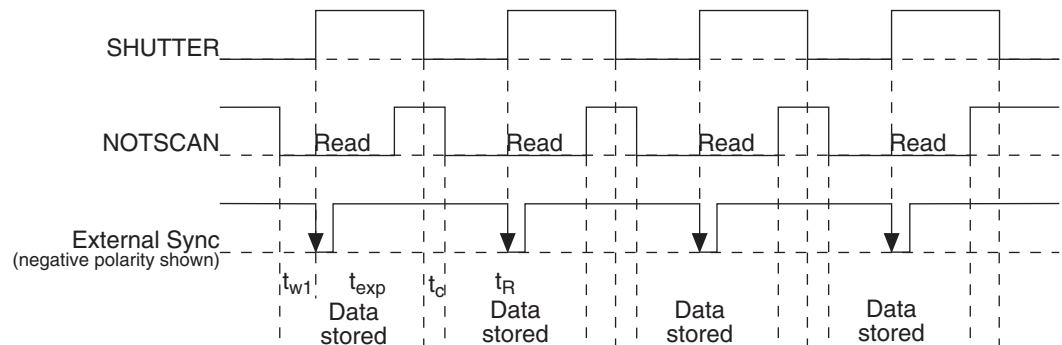
Figure 21. Frame Transfer where $t_{exp} + t_{w1} + t_c > t_R$

Figure 21 shows a case where the External Sync pulse arrives during readout of the array. Depending on the frequency of this signal and the frame rate of the camera, this pulse could also arrive *after* the readout. Figure 22 shows the timing under these conditions.
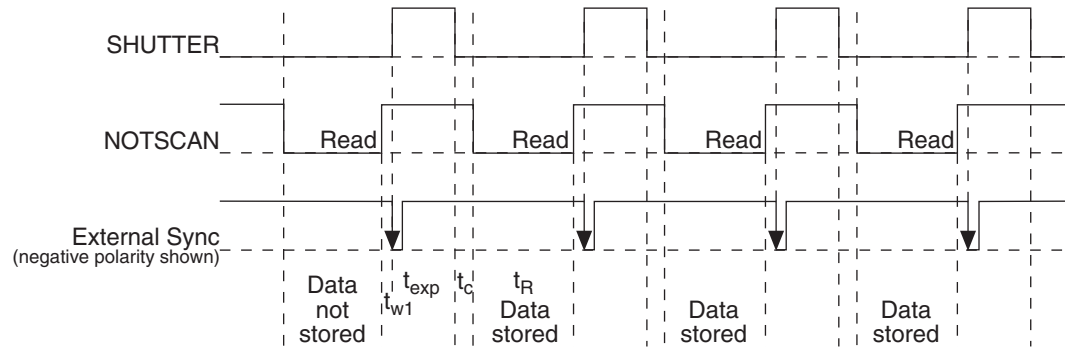
Figure 22. Frame Transfer where Sync. Pulse arrives after Readout

Edge vs. Level External Sync

In the previous figures describing External Sync timing modes in the I-Penta*MAX*, the Sync signal was shown being accepted on negative edges of the TTL input. Note that the I-Penta*MAX* camera can be programmed to allow this Sync to be accepted on positive edges as well. It can also be programmed to trigger on TTL high or low levels as well. See the appropriate Application Software manual for more information.

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Chapter 9
Exposure and Readout

Before each image from the CCD array appears on the computer screen, it must first be read, digitized, and transferred to the computer. A block diagram of the path of the image signal is shown in Figure 23.
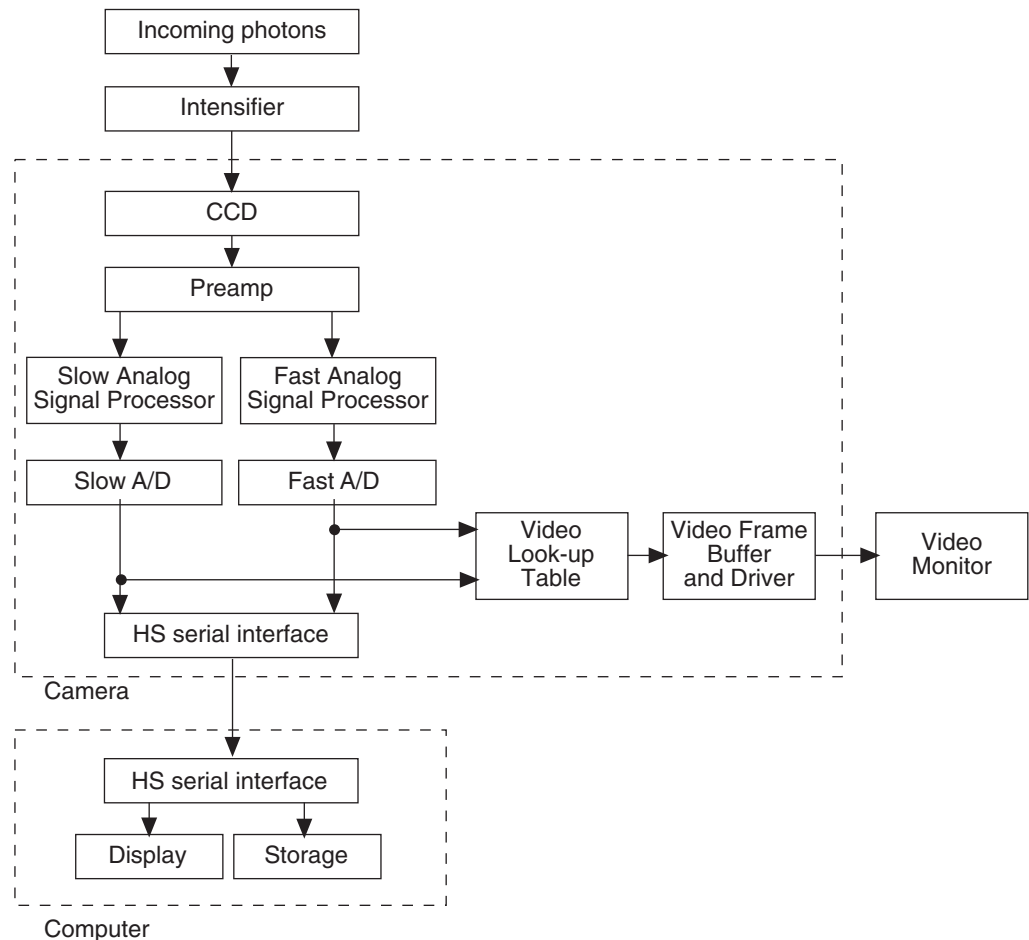
Figure 23. Block Diagram of Signal Path in System

The sections below describe the exposure, readout, and digitization of the image. Included are descriptions of binning for imaging applications and the specialized I-Penta*MAX* timing modes.

Exposure

Introduction

Charge coupled devices can be roughly thought of as a two-dimensional grid of individual photodiodes (called pixels), each connected to its own charge storage "well." Each pixel senses the intensity of light falling on its collection area, and stores a proportional amount of charge in its associated "well". Once enough charge accumulates, the pixels are read out serially.

CCD arrays perform three essential functions: photons are transduced to electrons, integrated and stored, and finally read out. CCDs are very compact and rugged. Unintensified, uncoated CCDs can withstand direct exposure to relatively high light levels and magnetic and RF radiation. They are easily cooled and can be precisely temperature controlled to within a few tens of millidegrees.

The MCP (microchannel plate) of the intensifier is composed of more than 10^6 individual miniature electron multipliers with an excellent input to output spatial geometric accuracy. Intensifier gain is varied by adjusting the voltage across the MCP or the voltage across the MCP output and the phosphor. This second parameter is a factory adjustment, as it affects both the gain and the resolution of the intensifier.

Detection of extremely weak Continuous Wave (CW) signals, e.g., luminescence and Raman scattering from solid state samples, is typically limited by the dark current of the intensifier's photocathode, usually referred to as the equivalent brightness intensity (EBI). All standard intensified cameras made by PI have the lowest EBI values possible.

The software allows the user to set the length of time the camera is allowed to integrate the incoming light. This is called the exposure time. In shutter mode the intensifier is normally enabled only during the exposure time (assuming the shutter cable is connected.)

Gated Operation

Gated operation is selected by setting the mode switch on the IIC-200 (IIC-100 or MCP-100) to **GATE**. In this mode, a Princeton Instruments pulser is required. The pulser gates the high-voltage power supply, which in turn gates the intensifier. The intensifier is biased on for the duration of each gate pulse, with the gate width set at the pulser. Note that the IIC-300 requires logic timing signals.

To prevent gate artifacts from appearing in the output, it is necessary that the intensifier not be gated while the CCD is being read out. This is usually accomplished by inhibiting the pulser with the **SHUTTER** signal, available at the **LOGIC OUT** connector if selected by the application software.

Shutter Mode Operation

In Shutter mode operation, selected by setting the mode switch on the IIC-200 (IIC-300, IIC-100 or MCP-100) to **SHUTTER** or **CW**, with no signal applied to the **SHUTTER IN** connector of the IIC-200 (IIC-300, IIC-100, or MCP-100), the intensifier is biased on continuously and the camera "sees light" for as long as the high voltage is applied. For this reason, the camera is particularly vulnerable to damage from excess light in Shutter mode operation. If the **SHUTTER** TTL output (provided at the **LOGIC OUT** connector when selected by the application software) is applied to the **SHUTTER IN** connector of

the IIC-200 (IIC-300, IIC-100, or MCP-100), the intensifier can be turned ON or OFF in much the same way as it is in Gated operation, but at slower speeds, allowing exposures from 50 µs to 23 hours to be set from software.

"Smearing" of signal features can occur if the CCD is exposed to light during readout. The additional light will result in continued charge accumulation even as charge is being moved across the CCD's surface to the shift register. The result is blurring of the image along one direction only.

The fraction of total signal due to smearing is the ratio of the amount of time spent shifting divided by the exposure time between frames. Faster shifting and/or longer exposure times will minimize this effect. Note that while 1% smear is insignificant in an 8-bit camera (256 gray levels), in a 12-bit camera (over 4,000 gray levels) 1% smearing is over 40 counts, enough to obscure faint features in a high dynamic range image.

With a full-frame CCD, smearing in shutter mode operation can be avoided by designing the experiment so no light falls on the intensifier during readout or so the intensifier is biased OFF during readout. The latter can be accomplished by connecting the **SHUTTER** signal (available at the **LOGIC OUT** connector when selected via software) to the **SHUTTER IN** connector of the IIC-200 (IIC-200 or MCP-100).

With a frame transfer CCD, smearing is minimized. This is due to the speed (a few milliseconds) at which the image is shifted under the masked portion of the array. Once the image is under the mask, it can be read out without being affected by light incident on the array.

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 more frequent readout is advisable, with signal averaging to enhance S/N 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, improves the S/N ratio approximately linearly with the length of exposure time. There is, however, a maximum time limit for on-chip averaging, determined by either the saturation of the CCD by the signal or the loss of dynamic range due to the buildup of dark charge in the pixels (see below).

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 noise.

Dark charge values vary widely from one CCD array to another and are exponentially temperature dependent. At the typical operating temperature of a standard I-Penta*MAX* camera, dark charge is reduced by a factor of ~2 for every 6º reduction in temperature. When acquiring data using long exposure times, taking a dark charge "background image" under identical conditions is essential. This image should be subtracted from the raw image in software.

> **Note:** Do not be concerned about either the DC level of this background or its shape unless it is very high, i.e., > 200 counts. What you see is not noise. It is a fully subtractable readout pattern. Each CCD has its own dark charge pattern, unique to that particular device. Simply turn off the intensifier and then acquire and save a dark charge "background image" under conditions otherwise identical to those used to acquire the "actual" image. Subtracting the background image from the actual image will significantly reduce dark-charge effects.

CAUTION

> If you have not just changed the temperature setting, a sudden change in the baseline signal may mean excessive humidity in the intensifier enclosure of the camera. If you observe this type of change, turn off the system immediately. An excess humidity condition should be corrected promptly or permanent damage not covered by the Warranty could occur. Have the unit serviced by Princeton Instruments or an authorized service facility of Princeton Instruments.

Readout of the Array

In this section, a simple 6×4 pixel CCD is used to demonstrate how charge is shifted and digitized. As described below, two different types of readout are available. Full frame readout, for full frame CCDs, reads out the entire CCD surface at the same time. Frame transfer operation assumes half of the CCD is for data collection and half of the array is a temporary storage area.

Full Frame Readout

The upper left drawing in Figure 24 represents a CCD after exposure but before the beginning of readout. The capital letters represent different amounts of charge, including both signal and dark charge. This section explains readout at full resolution, where every pixel is digitized separately.

Readout of the CCD begins with the simultaneous shifting of all pixels one column toward the "shift register," in this case the column on the far right. The shift register is a single line of pixels along one side of the CCD, not sensitive to light and used for readout only. Typically the shift register pixels hold twice as much charge as the pixels in the imaging area of the CCD.

After the first column is moved into the shift register, the charge now in the shift register is shifted toward the output node, located at one end of the shift register. As each value is "emptied" into this node it is digitized. Only after all pixels in the first column are digitized is the second column moved into the shift register. The order of shifting in our example is therefore D6, C6, B6, A6, D5, C5, B5, A5, D4....

After charge is shifted out of each pixel the remaining charge is zero, meaning that the array is immediately ready for the next exposure.

Below are the equations that determine the rate at which the CCD is read out. Tables of values for CCDs supported at the time of the printing of this manual also appear below.
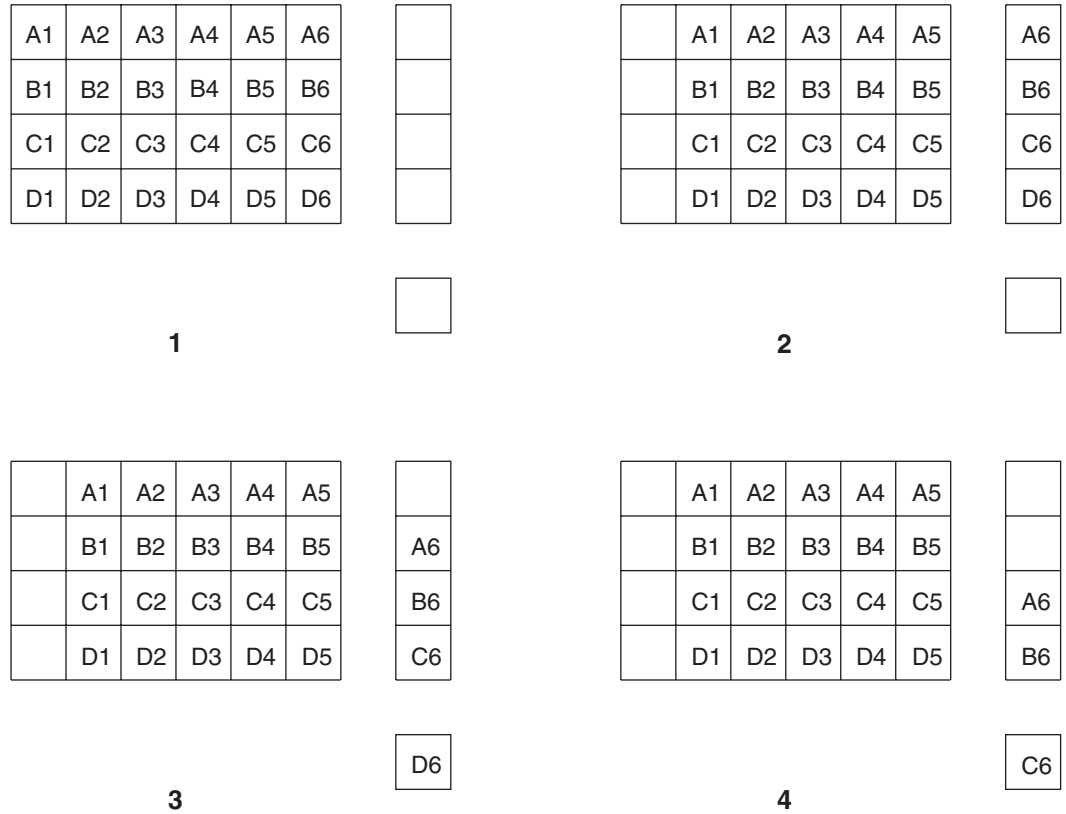
1

A1	A2	A3	A4	A5	A6
B1	B2	B3	B4	B5	B6
C1	C2	C3	C4	C5	C6
D1	D2	D3	D4	D5	D6

2

A1	A2	A3	A4	A5		A6
B1	B2	B3	B4	B5		B6
C1	C2	C3	C4	C5		C6
D1	D2	D3	D4	D5		D6

3

	A1	A2	A3	A4	A5	
	B1	B2	B3	B4	B5	A6
	C1	C2	C3	C4	C5	B6
	D1	D2	D3	D4	D5	C6
						D6

4

	A1	A2	A3	A4	A5	
	B1	B2	B3	B4	B5	
	C1	C2	C3	C4	C5	A6
	D1	D2	D3	D4	D5	B6
						C6

Figure 24. Full Frame at Full Resolution

The time needed to take a full frame at full resolution is:

$$t_R + t_{exp} + t_c \qquad (1)$$

where

> t_R is the CCD readout time,
>
> t_{exp} is the exposure time, and
>
> t_c is the shutter compensation time.

The readout time is approximately given by:

$$t_R = [N_x \cdot N_y \cdot (t_{sr} + t_v)] + (N_x \cdot t_i) \qquad (2)$$

where

> N_x is the smaller dimension of the CCD
>
> N_y is the larger dimension
>
> t_{sr} is the time needed to shift one pixel out of the shift register
>
> t_v is the time needed to digitize a pixel
>
> t_i is the time needed to shift one line into the shift register
>
> (t_s, the time needed to discard a pixel, appears below and in later equations)

The readout times for an EEV 512 × 512 array are provided in Table 4 below.

CCD Array	1 MHz Readout Time	5 MHz Readout Time
EEV 512 × 512	0.28 sec.	0.07 sec.

Table 4. Approximate Readout Time for the CCD Array

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

Image Readout with Binning

Binning is the process of adding the data from adjacent pixels together to form a single pixel (sometimes called a super-pixel), and it can be accomplished in either hardware or software. Rectangular groups of pixels of any size may be binned together, subject to some hardware and software limitations.

Hardware binning is performed *before* the signal is read out by the preamplifier. 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.

Figure 25 shows an example of 2 × 2 binning. Each pixel of the image displayed by the software represents 4 pixels of the CCD array. Rectangular bins of any size are possible.

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

The readout rate for n × n binning is approximated using a more general version of the full resolution equation. The modified equation is:

$$t_R = \left[N_x \cdot N_y \cdot \left(\frac{t_{sr}}{n} + \frac{t_v}{n^2} \right) \right] + \left(N_x \cdot t_i \right) \tag{3}$$

A1	A2	A3	A4	A5	A6
B1	B2	B3	B4	B5	B6
C1	C2	C3	C4	C5	C6
D1	D2	D3	D4	D5	D6

1

		A1	A2	A3	A4	A5+A6
		B1	B2	B3	B4	B5+B6
		C1	C2	C3	C4	C5+C6
		D1	D2	D3	D4	D5+D6

2

	A1	A2	A3	A4	
	B1	B2	B3	B4	
	C1	C2	C3	C4	A5+A6
	D1	D2	D3	D4	B5+B6

C5+C6
+D5+D6

3

	A1	A2	A3	A4	
	B1	B2	B3	B4	
	C1	C2	C3	C4	
	D1	D2	D3	D4	

A5+A6
+B5+B6

4
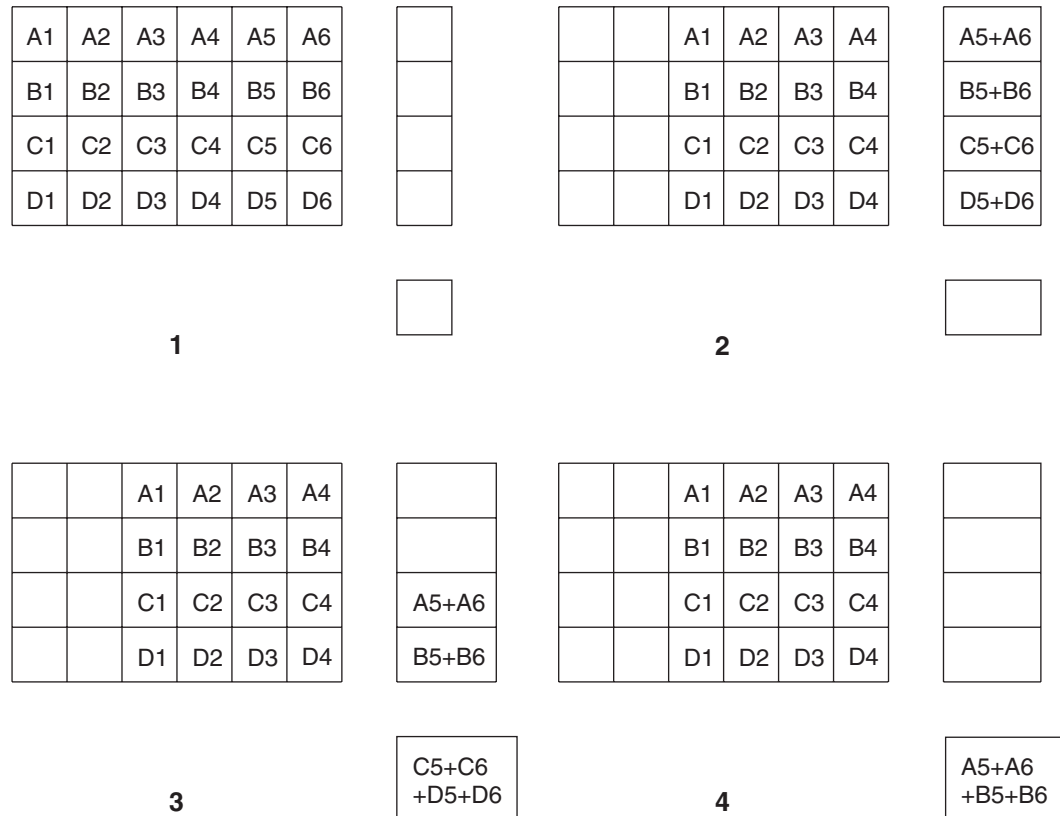
Figure 25. 2 × 2 Binning for Images

Binning in Software

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 as shown in Table 5. Consequently, if the total charge binned together exceeds the capacity of the shift register or output node, the data will be lost.

CCD Array	Imaging Section Well Capacity	Horizontal Shift Register Well Capacity	Preamp Node Well Capacity
EEV 512 × 512*	100×10^3 electrons	200×10^3 electrons	200×10^3 electrons

Table 5. Well Capacity for some CCD Arrays (in electrons)

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

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

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

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

Frame Transfer Readout

The I-Penta*MAX* supports frame transfer readout. Operation in this mode is very similar to the operation of video rate cameras. Half of the CCD is exposed continuously, raising the exposure duty cycle to nearly 100%. The other half of the CCD is masked to prevent exposure, and it is here that the image is "stored" until it can be read out.

Figure 26 shows the readout of a masked version of our sample 4×6 CCD. The shading represents the masked area (masking is on the array).
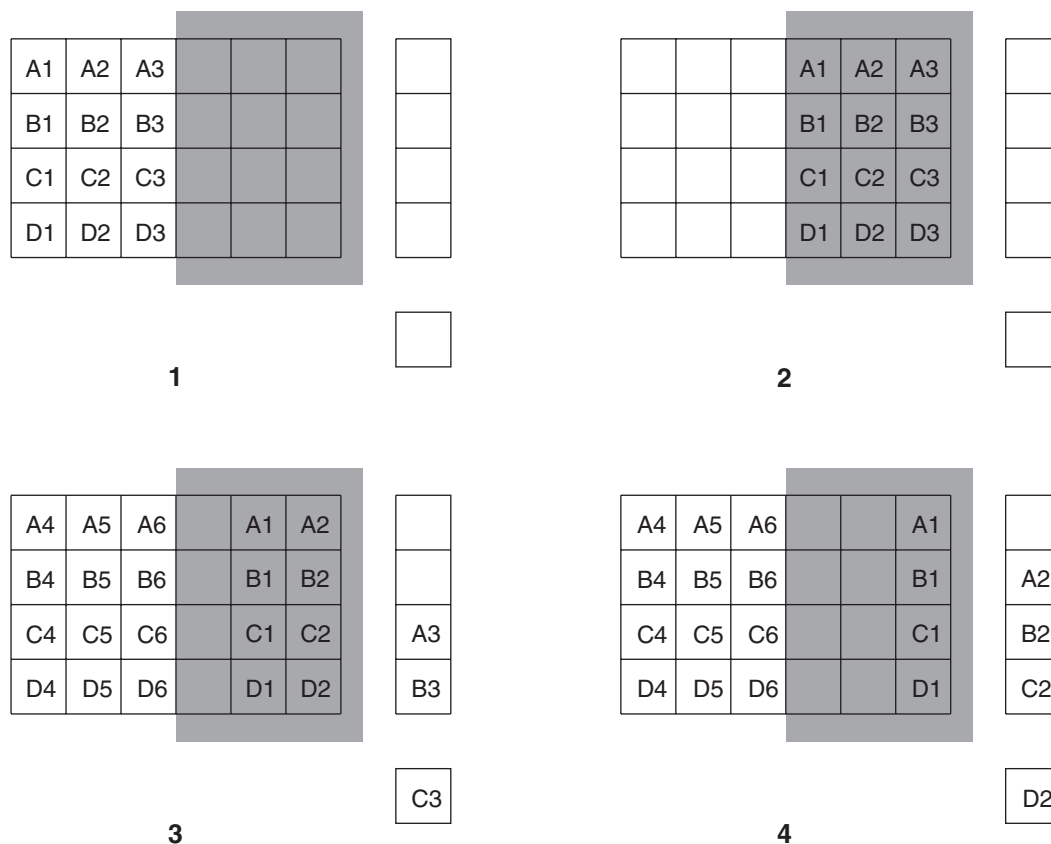
Figure 26. Frame Transfer Readout

Only the exposed region collects charge. At the end of the exposure, the charge is quickly shifted into the masked region. Since the shifting is accomplished in a short time, i.e., a few milliseconds, the incident light causes only minimal "smearing" of the signal. While the exposed region continues collecting data, the masked region is read out and

digitized. The percentage of smearing is given by the equation below, simply the time needed to shift all rows from the imaging area divided by the exposure time.

$$\frac{N_x t_i}{t_{exp}}$$

(6)

Digitization

During readout, an analog signal representing the charge of each pixel (or binned group of pixels) is digitized. The number of bits per pixel is based on both the hardware and the settings programmed into the camera through the software. The I-Penta*MAX* can contain up to two A/D converters with different readout rates settable through software.

Dual A/D Converters Option

There is provision in the I-Penta*MAX* Camera for two complete analog channels including separate A/D converters to provide optimum signal-to-noise ratios at both readout speeds. Because the readout noise of CCD arrays increases with the readout rate, it is sometimes necessary to trade off readout speed for high dynamic range. Although slowing the readout speed of a high-speed A/D converter gives some relief, a fast A/D converter will always be noisier than one designed for optimum noise performance. Only the I-Penta*MAX* Camera with its two analog channels, one optimized for high speed, the other for high precision, provides a completely satisfactory solution to this problem. For the most common system configurations, there will be a 5 MHz converter for the fastest possible data collection, and a 1 MHz converter for use where imaging with lower noise is desired. Switching between the channels is completely under software control for total experiment automation.

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Troubleshooting

Introduction

The following issues have corresponding troubleshooting sections in this chapter.

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Alarm Sounds Continuously	Page 72
Baseline Signal Suddenly Changes	Page 72
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Controller Is Not Responding	Page 73
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Excessive Readout Noise	Page 77
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Temperature Lock Cannot be Achieved or Maintained	Page 78

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

Alarm Sounds Sporadically

It is normal for the alarm to sound briefly when the high-voltage supply is first turned on. However, if the alarm sounds sporadically, contact the factory at once. This may indicate intensifier damage or another situation that requires immediate attention.

Alarm Sounds Continuously

Immediately reduce the light entering the camera. This can be done by decreasing the lens aperture, completely blocking the light into the camera window with a lens cap or equivalent, or by switching **MCP POWER/OFF** to "**OFF**" until you lower the source illumination.

If the alarm sounds continuously even when the illumination level is adequately low, switch the **MCP POWER/OFF** to "**OFF**" and switch the IIC-200 (IIC-300, IIC-100, or MCP-100) **POWER** to "**OFF**". Then contact the factory: this may indicate intensifier damage or another situation that requires immediate attention.

Baseline Signal Suddenly Changes

There are two possible reasons for this change:

- The temperature setting has been changed. In this case, a change in baseline signal is normal.

- There may be excessive humidity in the intensifier enclosure of the camera. If the temperature setting has not been changed and you observe a baseline signal change, turn off the system immediately. An excess humidity condition should be corrected promptly or permanent damage not covered by the Warranty could occur. Have the unit serviced by Princeton Instruments or an authorized service facility of Princeton Instruments.

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, begin with these simple checks:

- Turn off all AC power.

- Verify that all cables are securely fastened and that all locking screws are in place.

- Check for a burned-out fuse in the Temperature/ Power Supply power module. For information about changing a fuse, see "Fuses are not Correct for the Line Voltage" on page 77.

- Correct any apparent problems and turn the system on.

- If the system still does not respond, contact Technical Support.

Controller Is Not Responding

If this message pops up when you click on **OK** after selecting the Interface Type during **Hardware Setup** (under the WinView/32 **Setup** menu), the system has not been able to communicate with the camera. Check to see if the Temperature/Power Supply unit has been turned ON and if the interface card, its driver, and the interface cable have been installed.

- If the Temperature/Power Supply unit is ON, the problem may be with the interface card, its driver, interrupt or address conflicts, or the cable connections.

- If the interface card is not installed, close WinView/32 and turn the Temperature/Power Supply unit OFF. Follow the interface card installation instructions in Chapter 3 and cable the interface card to the "High Speed Serial" port on the rear of the camera. Then do a "Custom" installation of WinView/32 with the appropriate interface component selected: "PCI Interface" or "ISA Interface", depending on the interface card type. Be sure to deselect the interface component that does not apply to your system.

- If the interface card is installed in the computer and is cabled to the "High Speed Serial" port on the rear of the camera, close WinView/32 and turn the Temperature/Power Supply unit OFF. Check the cable connections and tighten the locking screws if the connections are loose.

- If the interface card was installed after WinView/32 has been installed, close WinView/32 and do a "Custom" installation of WinView/32 with the appropriate interface component selected: "PCI Interface" or "ISA Interface", depending on the interface card type. Be sure to deselect the interface component that does not apply to your system.

Error Indicator Lights on Temperature/Power Supply

The red **ERROR** indicator on the front panel of the Temperature/Power Supply will light when a temperature-control error condition is detected. At the same time, the temperature control loop will shut down *independent of the setting of the Temperature Control On/Off switch.* When this happens, the temperature will begin rising towards ambient, even though the yellow **STATUS** indicator remains lighted and *even if the error condition is corrected*. It is ***always*** necessary to cycle the power before normal temperature control operation can be re-established. Ordinarily you would turn off the power, identify and correct the error condition, and then turn the power back on and operate as usual.

Note: You may have to wait until the internal temperature of the camera reaches a certain temperature before you can resume temperature control.

Possible causes of an error indication include:

- The connector locking screws for the cable between the Temperature/Power Supply and the Camera need to be tightened. Check the locking screws and handtighten them if they are loose.

- The internal temperature of the camera has gotten too high, such as might occur if the operating environment is particularly warm or if the user is attempting to operate

at a temperature colder than the specified limit. Adjust the operating environment temperature.

- The Temperature/Power Supply has overheated; the most likely cause would be obstructed ventilation. There must be free access between the air in the room and the air intake on the **<u>bottom</u>** of the Temperature/Power Supply. Similarly, there must be free access between the back panel exhaust grill and the room atmosphere.

- The air filter at the bottom of the Temperature/Power Supply is dirty.

   1. Turn the Temperature/Power Supply unit **OFF** and unplug the unit from the AC power source.
   2. Place the unit upside down.
   3. Grasp the filter on the bottom of the unit and remove it.
   4. Shake it to dislodge the dirt.
   5. Reinstall the filter.
   6. Return the unit to its upright position and plug it into the AC power source.

CAUTION   Do not operate the Temperature/Power Supply unit with the filter removed.

Error Occurs at Computer Powerup

If an error occurs at boot up, either the interface card is not installed properly or there is an address or interrupt conflict. Turn off the computer, reinstall the interface card (make sure it is firmly seated), and reboot the system.

If an error occurs while you are using the WinView/32 program, check the interface selection on the **Hardware Setup|Interface** tab page (WinView/32). If the current choice is "High Speed PCI", change the selection to "PCI(Timer)". If the problem goes away, you can either correct the interrupt conflict or you can continue using PCI(Timer) for data transfer (data transfer is controlled by a polling timer rather than interrupts). Note that data transfer is slower in PCI(Timer) mode and data overrun more likely. Also, PCI(Timer) cannot be used to continuously acquire small Regions of Interest in asynchronous operation.

CAUTION   Since interrupts and DMA channels cannot be shared, make sure no other boards in your computer use this interrupt or these DMA channels.

Conflicts
One of the many advantages that PCI offers over ISA is that the whole issue of address and interrupt assignments is user transparent and under BIOS control. As a result, users typically do not have to be concerned about jumpers or switches when installing a PCI card. Nothing more should be required than to plug in the card, make the connections, and operate the system. As it turns out, however, in certain situations conflicts may nevertheless occur and user intervention will be required to resolve them.

Typical PCI motherboards have both ISA and PCI slots and will have both PCI and ISA cards installed. In the case of the ISA cards, the I/O address and Interrupt assignments will have been made by the user and the BIOS will not know which addresses and interrupts have been user assigned. When a PCI card is installed, the BIOS checks for

available addresses and interrupt levels and automatically assigns them so that there are no *PCI* address or interrupt conflicts. However, because the BIOS doesn't know about the user-assigned ISA I/O address and interrupt level assignments, it is possible that a PCI card will be assigned an address or interrupt that is already assigned to an ISA card. If this happens, improper operation will result. Specifically, the problems could range from erratic operation under specific conditions to complete system failure. If such a conflict occurs, because the user has no control over the PCI address and interrupt assignments, there will be no recourse but to examine the ISA assignments and change them to values which do not conflict. Most (but by no means all) ISA cards make provision for selecting alternative I/O addresses and interrupt levels so that conflicts can be resolved. Software is available to help identify specific conflicts.

The following example may serve to illustrate the problem. Suppose you had a system with an ISA network card, a PCI video card and an ISA sound card. Further suppose that you were then going to install a PCI Serial Buffer card. Before installing the PCI Serial card, the I/O address and interrupt assignments for the installed cards might be as follows.

Slot Type	Status	I/O Address	Interrupt
1 (ISA)	ISA Network Card	200-210	11
2 (PCI)	PCI Video Card	FF00-FFFF	15
3 (ISA)	ISA Sound Card	300-304	9
4 (PCI)	Empty	N/A	N/A

Table 6. I/O Address & Interrupt Assignments
before installing Serial Card

As shown, there are no conflicts, allowing the three peripheral cards to operate properly. If the PCI Serial card were then installed, the BIOS would interrogate the PCI cards and may reassign them new address and interrupt values as follows.

Slot Type	Status	I/O Address(s)	Interrupt
1 (ISA)	ISA Network Card	200-210	11
2 (PCI)	PCI Video Card	FE00-FEFF	11
3 (ISA)	ISA Sound Card	300-304	9
4 (PCI)	Princeton Instruments (RSPI) PCI Serial Card	FF80-FFFF	15

Table 7. I/O Address & Interrupt Assignments
after installing Serial Card

As indicated, there is now an interrupt conflict between the ISA Network Card and the PCI Video card (both cards have been assigned Interrupt 11), causing the computer to no longer function normally. This doesn't mean that the PCI Serial card is defective because the computer stops functioning properly when the Serial card is installed. What it does mean is that there is an interrupt conflict that can be resolved by changing the interrupt level on the conflicting Network card in this example. It is up to the user to consult the documentation for any ISA cards to determine how to make the necessary change.

Note: Changing the order of the PCI cards, that is, plugging them into different slots, could change the address and interrupt assignments and possibly resolve the conflict. However, this would be a trial and error process with no guarantee of success.

Diagnostics Software

Many diagnostics programs, both shareware and commercial, are available to help resolve conflicts. Most often, all that's required is a program that will read and report the address and interrupt assignments for each PCI device in the computer. One such program available from Princeton Instruments' Technical Support department is called PCICHECK. When the program is run, it reports the address and interrupt assignments for the first PCI device it finds. Each time the spacebar is pressed, it moves on to the next one and reports the address and interrupt assignments for that one as well. In a few moments this information can be obtained for every PCI device in the computer. Note that, even though there are generally only three PCI slots, the number of PCI devices reported may be larger because some PCI devices may be built onto the motherboard. A good strategy for using the program would be to run it before installing the PCI Serial card. Then run it again after installing the card and note any address or interrupt assignments that may have changed. This will allow you to easily focus on the ones that may be in conflict with address or interrupt assignments on ISA cards. It might be noted that there are many programs, such as the MSD program supplied by Microsoft, that are designed to read and report address and interrupt assignments, including those on ISA cards. Many users have had mixed results at best using these programs.

Operation

There are no operating considerations that are unique to the PCI Serial card. The card can easily accept data as fast as any Princeton Instruments system now available can send it. The incoming data is temporarily stored in the card's memory, and then transferred to the main computer memory when the card gains access to the bus. The PCI bus arbitration scheme assures that, as long as every PCI card conforms to the PCI guidelines, the on-board memory will never overflow.

Unfortunately, there are some PCI peripheral cards that do *not* fully conform to the PCI guidelines and that take control of the bus for longer periods than the PCI specification allows. Certain video cards (particularly those that use the S3 video chip) are notorious in this respect. Usually you will be able to recognize when memory overflow occurs because the displayed video will assume a split-screen appearance and/or the message **Hardware Conflict** will be displayed (WinView/32). At the same time, the LED on the upper edge of the PCI Serial card will light.

Users are thus advised not to take any actions that would worsen the possibility of memory overflow occurring when taking data. In that regard, avoid multitasking while taking data. Specific operations to avoid include multitasking (pressing ALT TAB or ALT ESC to start another program), or running a screensaver program.

Excessive Readout Noise

Excessive readout noise with the intensifier off indicates possible moisture accumulation in the CCD. This should be corrected promptly or permanent damage not covered by the Warranty could occur.

Normal camera noise is a function of the gain setting and temperature as well as CCD type, but is typically in the range of 1 ADU rms (6 ADU pk-pk). This is on top of offset that typically is about 40 counts. Moisture accumulation produces a coarser noise with many spikes ≥ 30 ADU. If these types of spikes occur, especially after the camera has been in use for an extended period, turn off the system immediately. Have the unit serviced by Princeton Instruments or an authorized service facility of Princeton Instruments.

Fuses are not Correct for the Line Voltage

The operating line voltage is auto-sensed by the Temperature/Power Supply unit and will automatically configure itself accordingly. However, the installed fuse will no longer be correct. Depending on the fuse rating, this could result in inadequate protection for the system or it could result in fuse failure.

To Change the Fuses:

1. Unplug the line cord from the Power Input assembly at the rear of the Temperature/Power Supply unit.

2. Insert a small screwdriver into the recess at the top of the Power Input assembly as shown in Figure 27 and pry open the cover.

3. Use the screwdriver to loosen the fuse carrier. Note the orientation of the arrow and then grasp the fuse carrier and pull it straight out of the Power Input assembly.

4. Remove the fuse and check to be sure its current rating is correct for the intended operating voltage. If the fuse is incorrect or has failed, replace the fuse.

5. After verifying that the fuse is correct, or after installing the new fuse in the carrier, should that be necessary, insert the fuse carrier back into the Power Input assembly. Make sure the arrow is pointing in its original direction.

6. Return the Power Input assembly cover to its original position and snap it into place to complete the procedure.

Voltage	Fuse
105-125 V (US)	2 A slow-blow, ¼″x1¼″
210-250 V (Europe)	1 A slow-blow, ¼″x1¼″

Table 8. Voltage and Fuse Selection
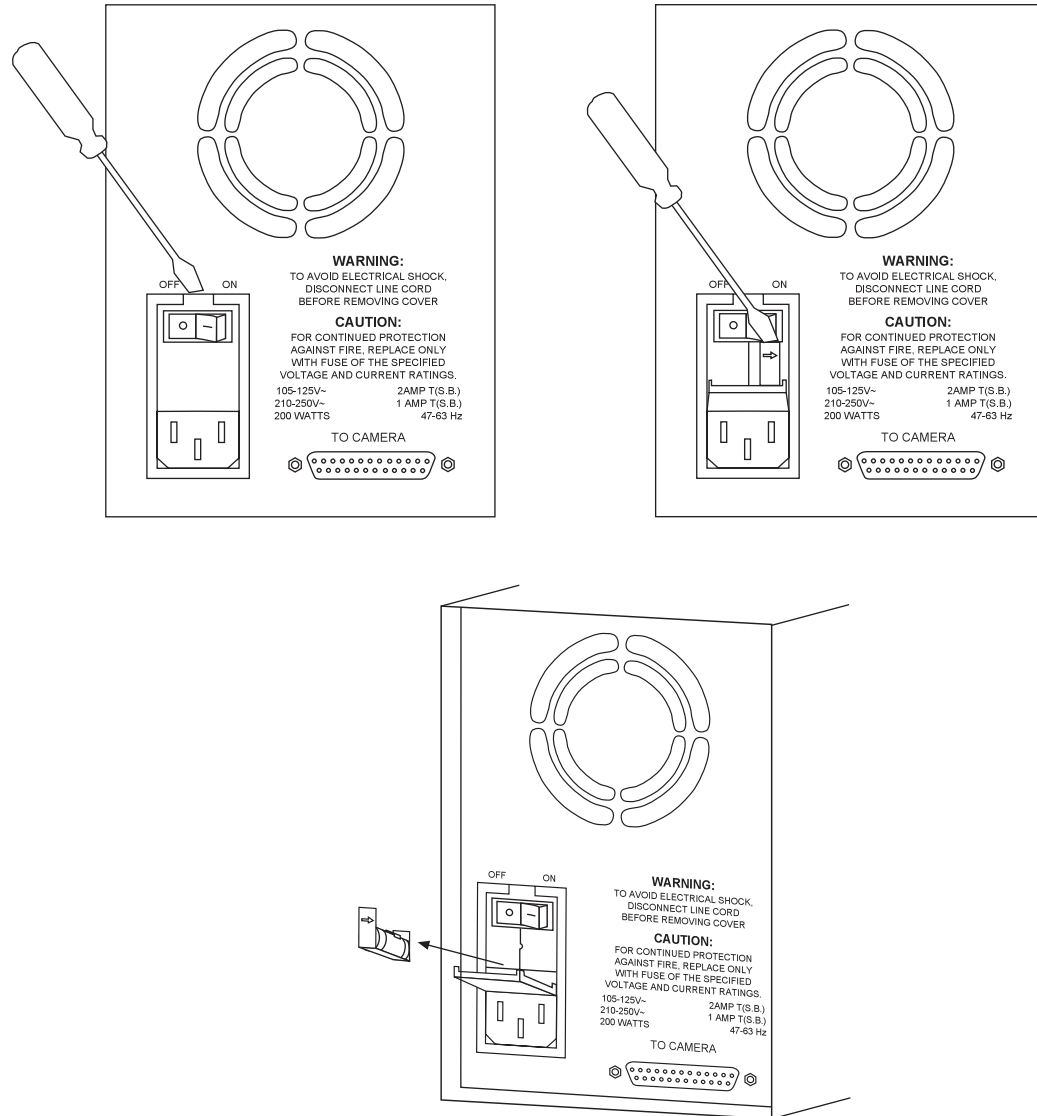
Figure 27. Power Input Assembly: Fuse Access

Temperature Lock Cannot be Achieved or Maintained

Possible causes could include:

- High ambient temperature.

- Airflow through the camera is blocked.

- The camera fan is not running.

- The Temperature/Power Supply filter is dirty.

- The connectors of the cable that interconnects the Temperature/Power Supply unit and the camera need to be secured.

- The target array temperature is not appropriate for your particular camera and CCD array.

- You are attempting to operate at a temperature colder than the specified limit. TE-cooled 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 in about ten minutes. Although the thermo-protection switch will protect the camera, you are nevertheless advised to power down and correct the operating conditions that caused the thermal-overload to occur.

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Specifications

Intensifier[*]

Types
Gen II: 18 mm gatable; resolution 30 line pairs per mm. Higher resolution tubes are available
Gen III: 18 mm gatable; resolution 50 line pairs per mm

Spectral Range
Gen II: Red-blue enhanced, 180-800 nm; Red enhanced, 360-920 nm
Gen III: 500-900 nm

Method of Coupling
1.5:1 fiber optics

Vignetting
With fiber optic coupling there is no vignetting. All pixels are illuminated.

Spatial Resolution
Gen II: 60 µm spot size FWHM.

Gen III: 28 µm spot size FWHM.

Geometric Distortion
Gen II: <1 pixel

Gen III: <1 pixel

Gating Speed
Gen II: Fast Gate Intensifier, 2-7 nsec FWHM; Slow Gate Intensifier, 50-70 nsec FWHM; see the pulser manual for the gating limits of your pulser.

Gen III: Fast Gate Intensifier, 15 nsec FWHM or faster, depending on gate pulse generation.

Gating On/Off Ratio
Gen II: 5×10^6:1

Gen III: 10^6:1

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[*] Princeton Instruments offers a wide variety of intensifiers suitable for use in the *Intensified PentaMAX*. Detailed intensifier characteristics are specified at the time of ordering.

CCD Array

EEV CCD-37

Format: $512 \times 512 \times 2$; 7.7×7.7 mm overall; 15×15 µm pixels

Temperature Control

Setting Mechanism: Temperature is set by friction-lock dial on front of Temperature/Power Supply.

Display: Digital display on front of Temperature/Power supply displays either the set temperature or the actual CCD chip temperature with a resolution of ±0.1°C.

Range: At 25°C ambient, temperature lock to approximately -20° C (CCD dependent) with air cooling only.

Time to Lock: At 25°C ambient, <10 minutes (typical) to temperature lock at -20°C

Control Precision: ±0.040°C over entire temperature range

Cooling

Air: Internal fan operates continuously.

CCD Cooling: -20 °C

Supplemental Liquid: Using back-panel ports, liquid coolant, including water, at a maximum pressure of 80 psi can be circulated through unit to extend temperature range. Ports are designed to accept ¼″ inner diameter Tygon tubing. ***Coolant cannot be chilled!***

Mounting

Camera: There is a ¼″ × 20 5/8″ deep threaded hole on the bottom of the camera to facilitate mounting.

Lens: Camera will accept either C-mount (threaded) or F-mount (bayonet) lenses, according to the mount specified at time of order.

Microscope: Adapters are available for mounting to most research microscopes. See Chapter 6 for more detailed information.

Inputs

EXT SYNC: TTL input (BNC) to allow data acquisition to be synchronized with external events. Sense can be positive or negative going as set in software. Synchronization and Trigger Modes are discussed in Chapter 8.

HIGH VOLTAGE: The high voltage from the Model IIC-200 High Voltage Power Supply (Model IIC-100 High Voltage Power Supply or Model MCP-100 Modular High Voltage Power Supply) is applied to this connector using the PI High-Voltage cable.

Outputs

VIDEO: 1 V pk-pk from 75 Ω, BNC connector. Either RS-170 (EIA) or CCIR standard video as specified when system was ordered. Requires connection via 75 Ω cable that must be terminated in 75 Ω.

LOGIC OUT: TTL output (BNC) for monitoring the camera status. The camera state being reported is selected by the application software. For a description of the individual signals provided, see *LOGIC OUT BNC Connector* on page 15. Additional information is provided in Chapter 8.

HIGH SPEED SERIAL: Data link to computer via proprietary cable connected to this 9-pin "D" connector. Cable lengths to 100 feet available. Optional fiber-optic connection available for greater distances.

Exposure Range

Gate Mode: ~10 ns to 1 ms (depends on intensifier and gate generation)

Shutter Mode: 500 μs to 23 hours (full frame or frame transfer)

A/D Converters

Converter range: 12 bits

Readout Rate: Fast, 5 MHz; Slow, 1 MHz (optional)

Linearity: less than 1% non-linearity.

Read Noise: 32 e⁻ RMS @ MHz; 20 e⁻ RMS @ 1 MHz.

Computer Requirements

The I-Penta*MAX* is most commonly used with a PCI bus type Pentium computer configured as follows.

Type: PCI-bus based Pentium (or better).

Memory (RAM): Minimum of 32 Mbytes; possibly more depending on experiment design and size of CCD Array.

Operating System: Windows 95 or higher.

Interface: Princeton Instruments (RSPI) PCI High-Speed Serial card. Computers purchased from Princeton Instruments as part of the I-Penta*MAX* system are shipped with the card installed.

Note: SUN workstation, SGI workstation, and MAC support are available. Contact factory for details

Miscellaneous

Dimensions: See Appendix B.

Camera Weight: 4.1 kg.

Power Supply Weight: 3.2 kg

Power Requirements: 105-125 or 210-250 V AC (autosense selection), 47-63 Hz, 200 watts maximum; required DC levels provided by power supply regulators. Power to camera is applied via cable between 25-pin connectors on back of camera and Temperature/Power Supply unit.

Environmental Requirements: Storage temperature -20° C to 55° C; Operating temperature 0° C to 30° C; Relative humidity <50%

TTL Input Requirements: Rise time ≤ 40 nsec, Duration ≥ 100 nsec.

Outline Drawings of
Camera & Temperature/Power Supply

Note: Dimensions are in inches (mm).
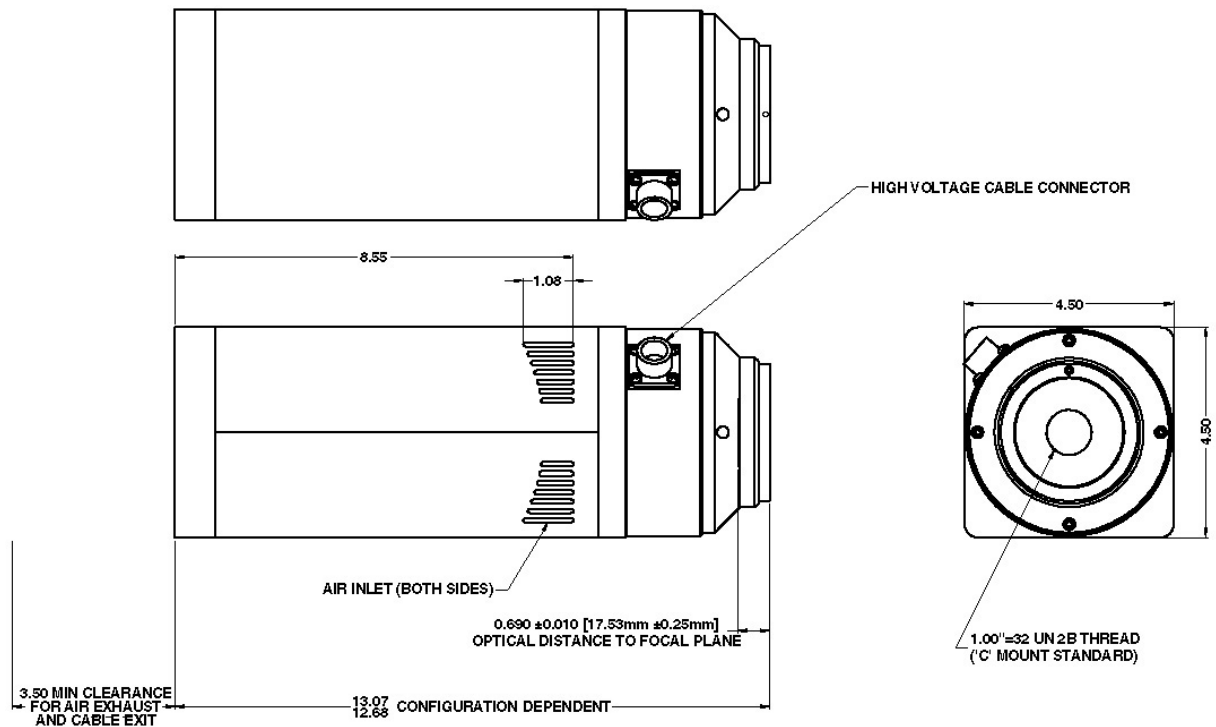
*Figure 28. I-Penta*MAX*: C-Mount*

HIGH VOLTAGE CABLE CONNECTOR

8.55

1.08

AIR INLET (BOTH SIDES)

4.50

4.50

1.831 ±0.010 [46.51mm ±0.25mm]
OPTICAL DISTANCE TO FOCAL PLANE

STANDARD NIKON 'F' MOUNT

3.50 MIN CLEARANCE
FOR AIR EXHAUST
AND CABLE EXIT

14.21
13.82   CONFIGURATION DEPENDENT
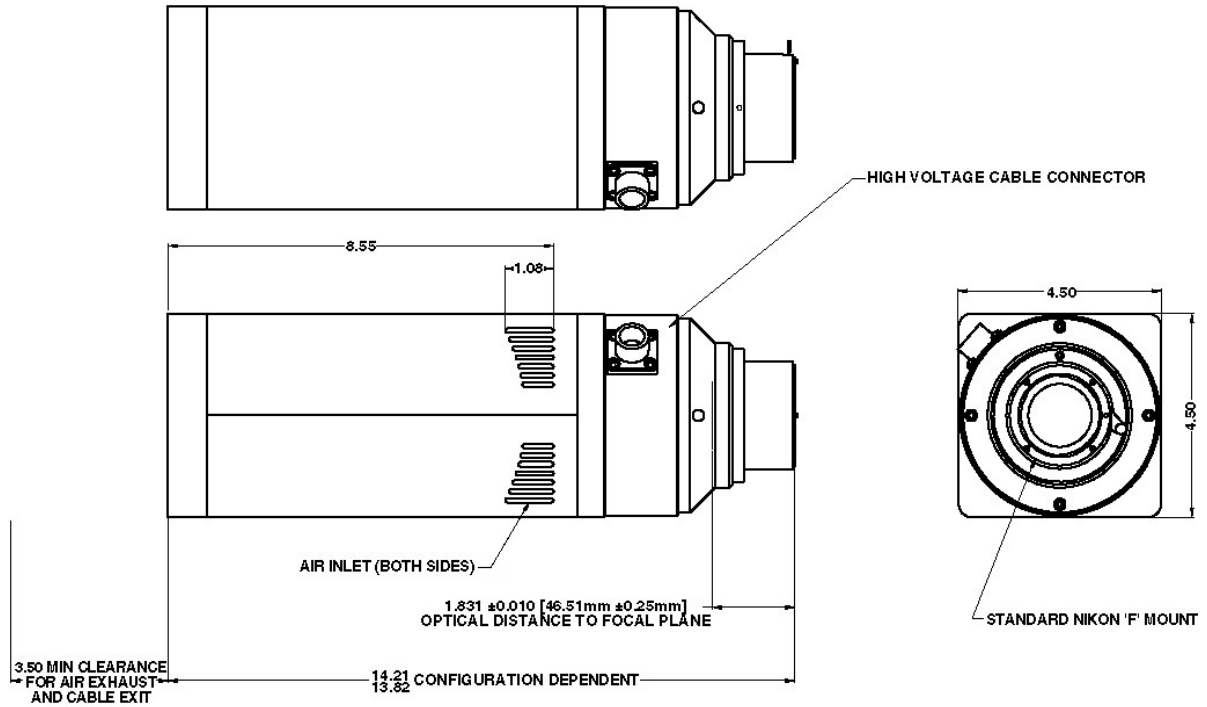
*Figure 29. I-Penta*MAX*: F-Mount*

6.42 (162.9)

11.74 (298.2)

4.90 (124.5)
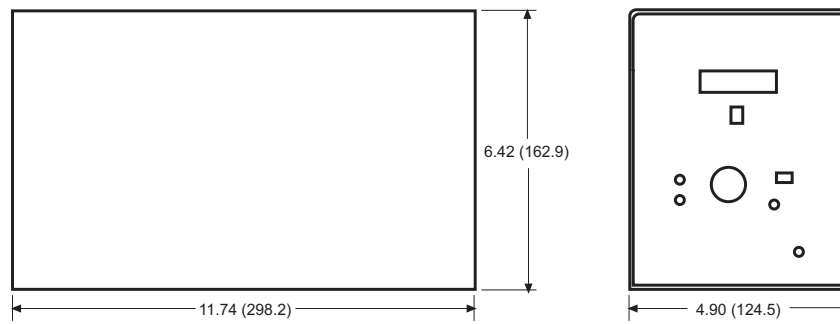
Figure 30. Temperature/Power Supply

Appendix C

Penta*MAX* Versions

Introduction

With time, the Penta*MAX* has evolved enhanced capabilities as reflected in the Version number of the instrument. To access the full capabilities, it is necessary that the Version be correctly selected in software. This can be easily done from the Hardware Setup pages of WinView/32 and WinSpec/32. A brief description of each version follows.

Version 1

Unit Prototype - none of these units are in the field.

Version 2

This camera version has the 1750-0165 PCB for scan control. This PCB does not have a hardware look-up table for video (video displays top 8-bits of data only), does not implement frame-transfer timing mode, and does not have an auto-stop frame count register.

Version 3

This camera version has the 1750-0256 PCB for scan control. This PCB has a hardware look-up table for video, implements frame-transfer timing mode, and has an auto-stop frame count register. This version also uses a 1750-0256 PCB which has an EPLD program version 2.0 (CS : 00339142) for U4. This EPLD has a bug that affects customers running the camera asynchronously. See Version 4 below.

Version 4

This camera version has the 1750-0256 PCB for scan control with an EPLD program version 2.1 (CS : 0033900C) for U4. This EPLD program corrects a bug that is present in ALL previous versions of the camera. The bug can cause the camera to return bad data after a Safe Mode software reset is performed.

Version 5

This camera version uses the 1750-0314 PCB for scan control and 175x-0166-D for the Serial Comm./Power PCB. These PCB's implement a variety of new features, including the following:

Read back of Serial NVRAM System ID information: This EEPROM must be programmed by production test/system test using the "NVRAM Windows Application," provided by the software department. This EEPROM will hold a variety of information about the camera system which will allow the hardware version of the camera to be detected by software (for the autoconfiguration of some parameters) and customer and test information to be stored with the hardware.

Ability to shut down the RS170 oscillator for noise critical applications: Because the video oscillator runs at an independent frequency from the rest of the system, it can be a source of asynchronous noise in the image data. If PI software is running a PentaMAX as a "Version 5," it will now shut down this oscillator if RS170 is not selected by the user.

Video buffer blanking has been made disjoint from the resetting of the camera: In previous versions of the camera, the video was blanked any time the camera was reset, which occurred between every frame when the camera was operated asynchronously (causing the video image to "blink"). Now the video is only blanked on power up unless explicitly blanked by the host software.

Camera can now hold more than one scan pattern at a time: This allows the implementation of video focus mode features that allow quick panning of the video around large image areas. It also allows the CCD to be cleaned using a different pattern than is used for scanning (which is important for continuous clean mode, described below). Note that the current release of PI software may not yet take advantage of these features.

Maximum possible shutter compensation time: Has been increased from 30ms to 62ms.

Continuous clean mode has been implemented: To use this feature the ADC (175x-0219) and preamp (175x-0224, Kodak only) EPLD programs need to be upgraded so that the interpretation of a newly implemented CLEAN instruction is done properly. DCN #2592 performs these program upgrades. These EPLD programs revisions are backward compatible with Version 4 scan control and serial comm/power hardware.

Software selection of back-panel BNC logic output: Choices are Not Scan (default), Cleaning, Logic 0, Logic 1, Not FT Image Shift, Not Ready, Shutter.

Ability to mask the End of Frame interrupt returned by the camera: Together with the addition of a generic Scan Control interrupt, which can be placed anywhere during the CCD scan cycle. These two features are particularly important to users who would like to interrupt their software at the beginning of a CCD frame instead of the end of the cycle.

Video look-up bank selection and 2X video zoom mode implemented: These features will allow quick change in the selection of the video look-up table and allow smaller CCDs images (particularly the EEV 576FT) to fill the entire RS170 monitor and run at higher frame rates to the video monitor (EEV576FT can run nearly 40fps to the RS170 monitor when 2X zoomed). Note that the current release of PI software may not yet take advantage of these features.

Virtual chip operation: This feature allows a portion of the array to be redefined as a "virtual" chip for enhanced data acquisition speed. Frame rates in excess of 100 frames per second can be obtained.

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Appendix D

Two-Shot Kinetics Mode

Princeton Instruments now supports a 2-shot kinetics mode in the PentaMAX ICCD system through a mini-application called PMX ICCD Kinetics App. The basic performance is as follows:

- ◗ Hardwired for PentaMAX 512 Frame Transfer Camera, Version 5. *This includes the PentaMAX Gen III ICCD, Version 5.*

- ◗ Programmable BNC set to Shutter output

- ◗ Shutter setting = None

- ◗ Prior to 1st shot, camera is in external synchronization mode with continuous cleans.

- ◗ Prior to 2nd shot, camera is in external synchronization only (no cleans).

- ◗ Exposure times for the 2 shots are equivalent; value can go down to 0.001 msec.

- ◗ User must provide the TTL triggers for the two shots in the following manner:

  - • TTL input into External Synchronization BNC connector on back of PentaMAX

  - • TTL triggers are rising edges

  - • and ONLY 2 triggers should be sent to the camera

The precise timing between the triggers is the responsibility of the user.

The second trigger must be delayed by Exposure Time + 1.8 msec as a minimum. Of this, the frame transfer shift time is 1.4 msec and the measured hardware reset time is 0.4 msec; the latter value is dependent on the CPU.

If the 2nd trigger is applied before the frame transfer shift is completed, a spurious short exposure will occur before the camera is reprogrammed and the images will not be read out.

If the 2nd trigger is given after the frame transfer shift but before the camera is fully reprogrammed, this trigger will be missed and the images will not be read out.

After the 2nd exposure, the image pair is read out and saved to disk.

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Appendix E
Virtual Chip Mode

Introduction

Virtual Chip mode (a WinView/32 option) is a special fast-acquisition technique that allows frame rates in excess of 100 fps to be obtained. For the Virtual Chip selection to be present, it is necessary that:

- the system be a PentaMAX, I-PentaMAX, MicroMAX (1 MHz or 5 MHz) or ST-133,

- that the camera have a frame transfer chip and,

- that the file WXvchip.opt be present in the same directory as the executable WinView/32 program. *Contact Technical Support for information regarding the availability of Wxvchip.opt.*

This method of data acquisition requires that the chip be masked as shown in Figure 31. Masking can be achieved by applying a mechanical or optical mask or by positioning a bright image at the ROI against a dark background on the remainder of the array.

In operation, images are continually piped down the CCD at extraordinarily high frames per second (FPS). The mini-frame transfer region is defined by an ROI as illustrated in Figure 31. The charge from this ROI is shifted under the frame-transfer mask, followed by a readout cycle of an ROI-sized region under the mask. Since the ROI is far from the serial register, the stored image is just shifted repeatedly with the readout and the first few images collected will not contain useful data. After the readout period, the next frame is shifted under the mask and another ROI sized frame is read out. The net result is a series of images, separated by spacer regions, streaming up the CCD under the mask. Refer to Table 9 for a listing of virtual chip sizes with their respective readout times and FPS.
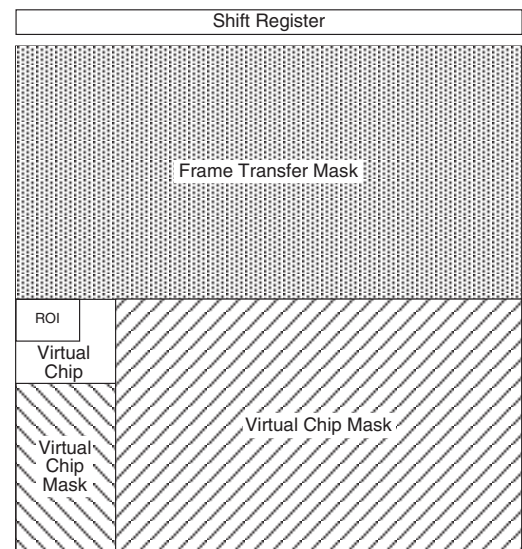
Figure 31. Virtual Chip Functional diagram

93

REGION	msec/FRAME	FPS*
160 × 160	7.07	141
98 × 98	3.08	324
89 × 89	2.72	367
68 × 68	1.74	574
56 × 56	1.39	719
51 × 51	1.14	877
41 × 41	0.92	1087
38 × 38	0.78	1282
32 × 32	0.68	1470
32 binned × 512	0.52	1923

Table 9. I-PentMAX, 5 MHz: Virtual Chip Size and Approximate Number of Frames per Second

* Virtual Chip speeds determined from scan code
  calculator assuming exposure equals readout time.
  Applies only to I-PentaMAX with 5 MHz ADC

Virtual Chip Setup

Introduction

If the Virtual Chip mode option has been installed, both WinView/32 and WinSpec/32
will support this technique.   The following procedure covers the basic hardware and
software setup for Virtual Chip operation.

Note: The Virtual Chip dialog box is discussed in detail in the next section.

Equipment:

I-PentaMAX (Version 5) with 512x512FT CCD array

IIC-200 and High Voltage cable

Temperature/Power Supply unit and Camera to Power Supply cable

Princeton Instruments (RSPI) PCI Interface Card and High Speed Serial (TAXI)
cable

75 Ω BNC cable

Suitable Host Computer

Software:

WinView/32, version 2.4 or higher

WXvchip.opt installed in the same directory as the executable WinView/32 program

Assumptions:

- You are familiar with the WinView/32 software and have read the hardware manuals.

- Masking is for a 41x41 pixel Virtual Chip with its origin at 1,1.

System Connection Diagram:
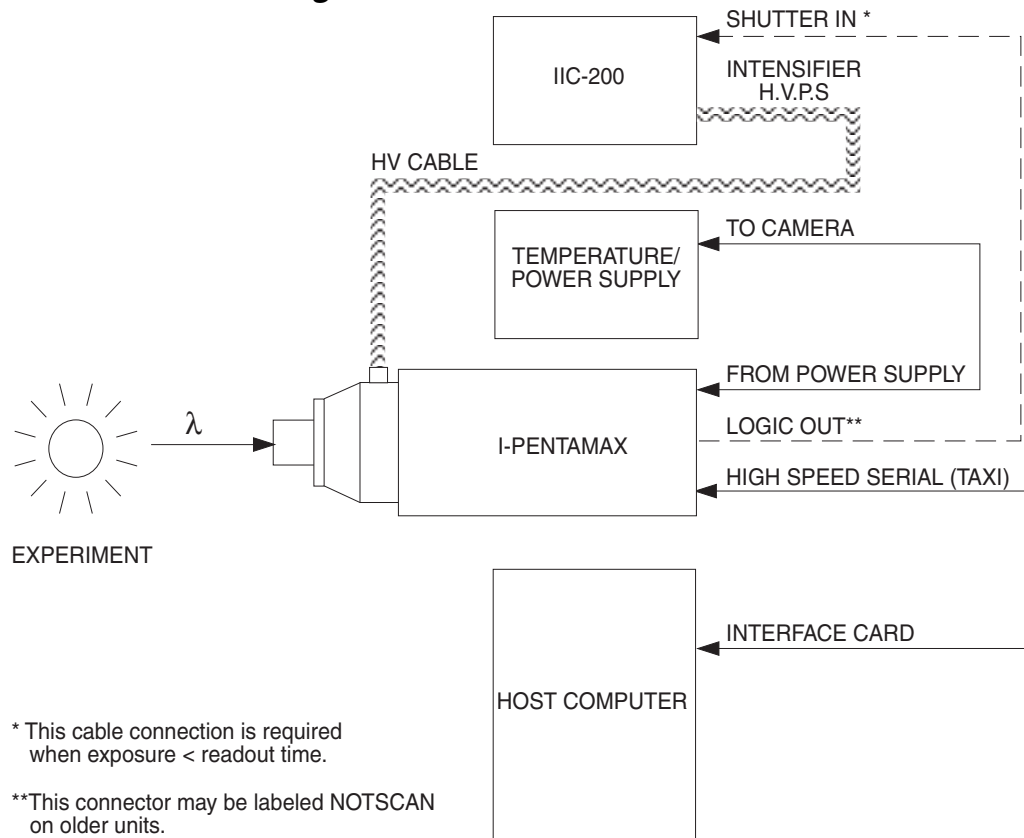
Figure 32. System Diagram: I-PentaMAX with IIC-200

Procedure:

1. Verify that the power is **OFF** for **ALL** system components (including the host computer).

2. Verify that the correct line voltages have been selected and that the correct fuses have been installed in the IIC-200 Image Intensifier Controller and the Temperature/Power supply unit (autoselecting for line voltage).

3. Verify that the HV connectors on the I-PentaMAX camera and the IIC-200 have identical labels (for example, both say "USE ONLY WITH GEN III").

4. In the center panel on the front panel of the IIC-200, put all of the switches in their DOWN positions (GATE, OFF, and OFF) and turn the MCP GAIN dial fully counter-clockwise (0 gain).

5. Connect the TAXI cable to the interface card at the host computer and to the **High Speed Serial** connector at the rear of the camera. Tighten down the locking screws.

6. Connect the **Camera-Power Supply** cable to the **TO CAMERA** connector on the rear of the Temperature/Power supply unit and to the **FROM POWER SUPPLY** connector at the rear of the camera. Tighten down the locking screws.

7. If it has not been installed already, connect a line cord from the Power Input assembly on the back of the Temperature/Power supply unit to a suitable AC power source.

8. Reconfirm that the IIC-200 **POWER** switch is set to "**OFF"**.

DANGER

⚠

The high voltage cable carries *lethal* voltages to the image intensifier (as much as 10,000 Volts). *Never* turn on the high-voltage power supply (IIC-100, IIC-200, or IIC-300) or a pulser equipped with the MCP-100 modular high-voltage supply unless both ends of the high voltage cable are connected. A cable connected at one end only is not only hazardous, but is susceptible to arcing and subsequent erratic operation due to the formation of carbon tracks.

WARNING!

The high voltage cable should be handled with care. Dropping the cable or banging the connectors may damage the pins, resulting in a poor or intermittent connection.

9. Connect the **HV Supply** cable to the HV output connector on the rear of the IIC-200 and to the HV input connector on the nose of the camera. To ensure proper electrical connection:

    a. Tighten the cable connector a couple of turns and then push down on the connector collar.

    b. Repeat the tightening and pushing down until the cable connector is fully seated.

    c. Repeat Steps a-b for the other end of the cable.

10. If it has not been installed already, connect a line cord from the Power Input assembly on the back of the IIC-200 to a suitable AC power source.

11. **OPTIONAL.** Connect a 75 Ω BNC cable from the **SHUTTER IN** connector on the rear of the IIC-200 to the **LOGIC OUT** connector on the rear of the camera. This setup is required for exposure times < the readout time.

12. Turn on the Temperature/Power Supply unit and set the temperature (-20°C is the coldest setting) and wait until the temperature locks.

13. Following the intensifier precautions in this manual and in the IIC-200 manual, press the IIC-200 **POWER** switch to "**ON**".

    a. Verify that the **MCP GAIN** setting is "**0**".

    b. Set the **MCP POWER/OFF** switch to "**MCP POWER**". The audible intensifier alarm should beep when the high voltage is applied. If it continues to beep, switch **MCP POWER/OFF** back to "**OFF**" and contact Princeton Instruments Technical Support.

    c. Leave **SHUTTER/GATE** switched to "**GATE**" and **AUTOBRIGHT/CONTROL** switched to "**OFF**".

14. Turn on the host computer and select the WinView/32 icon.

15. From the **Setup** menu, select **Hardware**, and enter the following settings:

Controller/CCD tab card

- **Controller:** PentaMAX

- **Controller Version:** 5

- **CCD Type:** appropriate frame transfer array (EEV 512x512FT, for this procedure)

- **Shutter Type:** None

- **LOGIC OUT Output:** Shutter

- **Readout Mode:** Frame Transfer

Interface tab card

- **Type:** the appropriate interface card. For this procedure, the selection is High Speed PCI.

Cleans/Skips tab card

- **Number of Cleans:** 1

- **Number of Strips per Clean:** 512

- **Minimum Block Size:** 2

- **Number of Blocks:** 5

16. From the **Setup** menu, select **Virtual Chip**, and enter the following settings:

    - **High Speed Mode Enabled**

    - **Virtual Chip Definition:** The settings below assume a 41x41 pixel virtual chip. The X and Y dimensions are established by the external mask. The virtual chip is fully flexible in the X direction. However, the set of choices for the Y-dimension has been pre- selected for optimal performance. Note that the origin point that Princeton Instruments uses for a CCD array is 1,1.

        - **Chip Y Dimension:** 41. Select this dimension from the drop down list.

        - **Chip X Dimension:** 41. Enter this dimension manually.

17. Click on the **Load Default Values** button. This enters the default ROI values. These values are: Start pixels of 1,1; End pixels based on the Chip Y and Chip X dimensions; and Groups of 1.

    - **Region of Interest:** The settings below assume a 41x41 pixel ROI (i.e., the entire virtual chip). An ROI that is a subset of the virtual chip can be defined.

X Start: 1	**Y Start:** 1
X End: 41	**Y End:** 41
X Group: 1	**Y Group:** 1

    - Click on the **Download Virtual Chip Definition** button. This will download the definition, set up the ROI, and calculate the readout time.

- Observe the calculated readout time. If you need a shorter period, change the settings (for example, enter a smaller Y-dimension or use binning in the Y-direction) and click on the **Download Virtual Chip Definition** button again.

- Click on **Close**.

18. From the **Acquisition** menu, select **Experiment Setup** and enter the following settings:

   Main tab card

   - **Exposure Time:** Enter a value. The exposure time can either be greater than the readout time or it can be equal to the readout time. If you want an exposure time > readout time, enter a value larger than the readout time calculated when the virtual chip definition was downloaded. If you want an exposure time = readout time, enter 000 sec.

   - **Number of Images:** Enter the desired number of images.

   - **Use Region of Interest**

   - **Accumulations:** 1

   ADC tab card

   - **Type:** FAST

   ROI Setup tab card: Make no changes to the settings on this tab card unless you have re-enabled Normal Operating Mode. ROI setup for Virtual Chip (High Speed Mode) is performed through the Virtual Chip dialog box.

19. From the **Setup** menu, select **Environment**.

   Note: When setting up for focusing, the number of **Frames/Interrupt** should be left at 1.

   - **DMA Buffer (Mb):** By default, the buffer size is 8 Mb. Using the following formula, calculate the amount of DMA memory required:
     $$\mathbf{X \times Y \times \#Frames \times (2\ bytes/pixel)}.$$
     For example, the buffer size required for a 41x41 virtual array acquiring 1000 frames would be $\mathbf{41 \times 41 \times 1000\ frames \times (2\ bytes/pixel) = 3.4\ Mb}$. If the calculated value is greater than 8 Mb, enter the appropriate size.

     Note: This value is not enabled until you restart your computer.

   - **Frames/Interrupt:** If the number of frames is greater than 256 (the pre-programmed slot limit for a PCI card), increase the number of **Frames/Interrupt** value. Use the formula **#Frames/256** and round the result to the next highest integer to calculate that value. For example, 1000 frames/256 will result in 3.9, so enter 4.

     Note: This value should be 1 for **Focus** mode.

20. Click on **OK** after you have finished entering the Environment settings.

21. Set the **SHUTTER/GATE** switch on the IIC-200 to "**SHUTTER**". If the audible alarm beeps, immediately reduce the light level or immediately switch **MCP POWER/OFF** to "**OFF**" and reduce the light level. Once you have reduced the light level, switch **MCP POWER/OFF** back to "**MCP POWER**" (if you turned it "**OFF**") and try again.

22. Place a suitable target in front of the camera and click on **Focus** to verify that the camera is seeing the target.

23. Make any focusing, gain, or other adjustments necessary to fine-tune the image.

24. Stop running in **Focus** mode.

25. Now click on **Acquire**.

Experimental Timing

Triggering can be achieved through the software via the **Software Trigger** timing mode (selectable on the **Experiment Setup** dialog box, **Timing Mode** tab page) or it can be achieved via the **Ext Sync** input on the rear of the camera. Triggering from the **Ext Sync** input allows you to acquire a single image per TTL pulse. If **Software Trigger** has been selected, back-to-back collection of the requested number of images will be initiated when **Acquire** is selected: no further TTL trigger input is required.

Virtual Chip dialog box
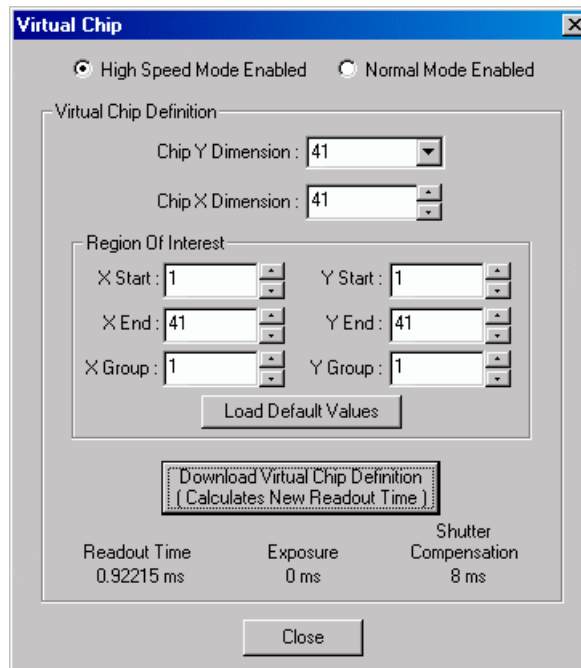
Figure 33. Virtual Chip dialog box

Clicking **Virtual Chip** on the **Setup** menu displays the **Virtual Chip** dialog box. When the **High Speed Mode Enabled** radio button is selected, all of the fields and buttons on the box will be activated as shown in Figure 33.

Mode: Radio buttons allow the choice of **High Speed Mode Enabled** and **Normal Mode Enabled**. In the normal mode, the external masks would ordinarily be withdrawn, allowing normal frame-transfer operation. All of the parameter settings on the screen are grayed out if **Normal Mode Enabled** is selected. When **High Speed Mode Enabled** is selected, high speed frame rates using the virtual chip can be obtained as described above.

Chip Y Dimension: This is the Y range established by the external mask.

Chip X Dimension: This is the X range established by the external mask.

ROI: The X and Y Start, End and Binning (Group) values can be entered. The ROI can be as large as the virtual chip area established by the external mask or a subregion.

Load Default Values: Fills in the region of interest X and Y End values based on the Chip X and Y Dimension entries. By default, the ROI origin is at 1,1 and the Group values are both 1.

Download Virtual Chip Definition: Sends the virtual chip parameter values to the controller's non-volatile memory. If a virtual chip definition is already stored there, you will be given an overwrite warning.

Readout Time: Reported readout time that will result with the current virtual-chip parameter values.

Exposure Time: Reported current exposure time that will result with the value entered in the **Experiment Setup** dialog box.

Shutter Compensation Time: Reported value; depends on selected shutter type.

Close: Closes Virtual Chip dialog box.

Tips

▶   If mechanical masking is used, the mask can be a static one (fixed dimensions) in which case, multiple masks should be made to accommodate a variety of imaging conditions. Alternatively, a more flexible mask can be manufactured by taking two thin metal sheets with a square hole the size of the exposed region of the CCD cut in the center. This would be 512×512 pixels at 15 microns per pixel = 7.68 mm $\times$ 7.68 mm for the non-intensified PentaMAX. For cameras with a 1.5:1 fiber-optic taper, the aperture will have to be larger since the intensifier is coupled via a taper with a net reduction. These masks should be anodized black to prevent reflections in the optical system and they should be very flat. These two sheets can then be slid relative to one another to achieve any rectangular shape required. The sheets should be placed flat in the optical plane and their openings should be centered on the optical axis. Ideally they should be able to move with an accuracy of 2-3 pixels per step (30-45 microns for non-intensified and 46-70 microns in the intensified PentaMAX) in the X and Y directions.

▶   Running the camera in CW mode with 0.0 msec exposure time will result in the fastest acquisition time. Under these conditions, the acquisition time is limited by the readout time of the ROI. *Do not use the coaxial connector to the SHUTTER IN input of the IIC-200 when exposure is 0.*

▶   When you return the system to "Normal" chip mode (radio button on Virtual Chip dialog box), you should also open the Experiment Setup dialog box at the ROI Setup tab card and click on the ClearAll button to clear the ROI setup downloaded for Virtual Chip operation.

- ➧ If frame acquisition appears to be slow in Focus mode, check the Frames/Interrupt value on the Environment dialog box and reset the value to 1 if it is greater than 1.

- ➧ When processing large stacks of data, you may want to use a third-party scientific image processing package.

- ➧ Use the 15' HV cable when performing non-gated (CW) experiments and the shorter version of that cable when performing gated experiments.

- ➧ When running at high FPS, you may see tailing from the phosphor in subsequent image frames. This is due to the long-lived emission from the intensifier phosphor. For the standard phosphor, this signal has a decay rate (exponential 100%-1%) of approximately 3 ms. If the phosphor signal is an issue, you can decrease the FPS or correct the data by subtracting the residual signal from subsequent images (essentially a negative exponential decay). Contact Princeton Instruments for information about intensifiers with high speed phosphors.

- ➧ Due to CCD design, you may see some edge artifacts when acquiring data from the entire virtual chip. Crop these artifacts by defining an ROI that is slightly smaller than the virtual chip dimensions.

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Warranty & Service

Limited Warranty

Princeton Instruments, a division of Roper Scientific, Inc. ("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.

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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, 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 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 Princeton Instruments authorized representative/distributor for repair information and assistance, or visit our technical support page at www.princetoninstruments.com.

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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, 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 Princeton Instruments factory or, at our option, a factory-authorized service center. You are responsible for the shipping costs to return the product to Princeton Instruments. International customers should contact their local Princeton Instruments representative/distributor for repair information and assistance or visit our technical support page at www.princetoninstruments.com.

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

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Princeton Instruments warrants that the cooling performance of the system will meet our specifications over the lifetime of an XP detector or 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.

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Sealed Chamber Integrity Limited 24 Month Warranty

Princeton Instruments 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

Princeton Instruments 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.

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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 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 Princeton Instruments technical support staff or our authorized service representative. *See Item 12 in the following section of this warranty ("Your Responsibility") for more information.*

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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 Princeton Instruments.
2. You must notify the 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 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 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 Princeton Instruments factory or one of our authorized manufacturer's representatives or distributors.
6. Unless specified in the original purchase agreement, 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;
   - 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 Princeton Instruments.
8. After the warranty period has expired, you may contact the Princeton Instruments factory or a 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 Princeton Instruments' liability exceed the cost of the repair or replacement of the defective product or part.

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12. When contacting us for technical support or service assistance, please refer to the Princeton Instruments factory of purchase, contact your authorized Princeton Instruments representative or reseller, or visit our technical support page at www.princetoninstruments.com.

Contact Information

Roper Scientific's manufacturing facility for this product is located at the following address:

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

Tel: 800-874-9789 / 609-587-9797
Fax: 609-587-1970

Technical Support E-mail: techsupport@princetoninstruments.com

For technical support and service outside the United States, see our web page at www.princetoninstruments.com. An up-to-date list of addresses, telephone numbers, and e-mail addresses of Roper Scientific's overseas offices and representatives is maintained on the web page.

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ST-133 Controller Addendum

Introduction

Thank you for purchasing a Princeton Instruments cameras system. Princeton Instruments is presently phasing in a new improved version of the ST-133 Controller. Depending on the ship date of your system and the status of manual revision, we are including this addendum to point out the differences between the ST-133A and the ST-133B (see Figure 1). *All operating instructions in this manual apply to the new Controller.*

Old ST-133A Version

New ST-133B Version

Figure 1. ST-133A Controller (left) and ST-133B (right)

The design changes include:

- Case redesign

- Power switch re-location and replacement

- Increased Power Rating and changed fuse requirements

Case Redesign

As part of the repackaging and enhancement of the ST-133 Controller, the ST-133A's paneled case has been replaced with a sleeve-type case for the ST-133B. This construction reduces electronic noise generated by variations in grounding. In addition, this redesign and other mechanical modifications have reduced the weight by 0.5 lbs/.23 kg.

Note: Please use the front and back bezels to move and carry the Controller (see Figure 2 on the next page).

E:\Manuals\Controller\ST-133B\ST-133B Addendum.doc

Figure 2. Carrying the ST-133B

ST-133B Power Switch

For the ST-133B, the power switch has been re-located to the back of the Controller and is positioned above the power module. To eliminate unwanted light sources around optical setups, the power switch no longer includes a built-in LED.
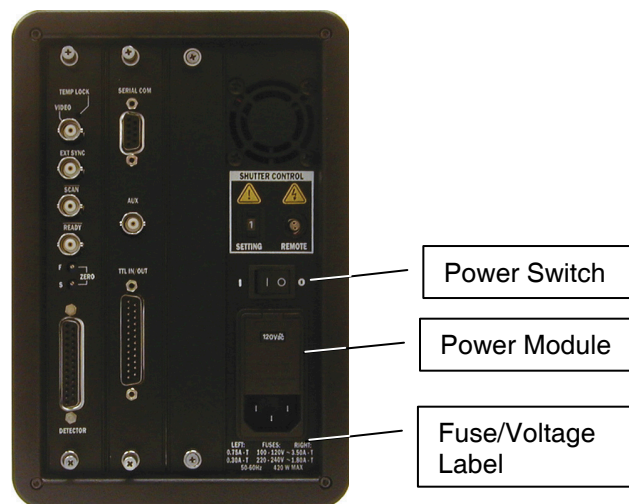

Figure 3. ST-133B Back Panel

ST-133B Power Rating and Fuse Requirements

This manual may include a Fuse and Voltage table that refers to the ST-133A; ignore this table and refer to the Fuse/Voltage label on the back of the ST-133B or to the table below for the correct information.

LEFT Fuse	Voltage	RIGHT Fuse
~0.75A-T	100-120V	~3.50A-T
~0.30A-T	220-240V	~1.80A-T
50-60 Hz 420 W MAX		

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