Princeton Instruments

ST-133 5MHz Controller

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BEYOND IMAGING

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Manual Overview

Chapter 1*, *Description provides an overview of the ST-133 5MHz Controller and Camera.

Chapter 2, Getting Started discusses introductory topics such as unpacking, equipment inventory, grounding and power requirements. It also includes detailed descriptions of the controller and camera features, together with information on mounting the camera and lens.

Chapter 3, Installing the Computer Interface provides detailed directions for mounting the High Speed Serial card in the computer and connecting it with the Controller.

Chapter 4, First Light provides a step-by-step procedure for placing the system in operation the first time.

Chapter 5, Temperature Control discusses how to establish and maintain temperature control. Also provides information on the effects of long-term vacuum degradation on cooling capability and temperature control.

Chapter 6, Timing Modes discusses the basic Controller timing modes and related topics, including Synchronous vs. Asynchronous, Free Run, External Sync, Continuous Cleans and Frame Transfer.

Chapter 7, Exposure and Readout discusses Exposure and Readout, together with many peripheral topics, including shuttered and unshuttered exposure, saturation, dark charge, and frame-transfer readout.

Appendix A, Specifications includes complete controller and camera specifications.

Appendix B, TTL In/Out Function discusses the purpose and operation of the TTL In/Out Function.

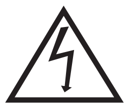
AppendixC, Cleaning Instructions discusses how to clean the system Controller, Camera and optics.

Appendix D, Outline Drawing contains outline drawings of the Controller and Camera.

Appendix E, Plug In Modules provides a brief overview of the plug-in modules, including directions for their installation and removal.

Safety Related Symbols Used in This 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 t 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.

Chapter 1
Description

Figure 1. The Model ST-133 5MHz Controller.

Introduction

Overview: The Model ST-133 5MHz is a compact, high performance CCD Camera Controller for operation with type TE[*]CCD 5MHz cameras. Designed for high speed and high performance image acquisition, the ST-133 5 MHz provides truly simultaneous video and digital outputs with rapid updating of the video image. As a result, it is easier to select a field of view and focus the system optics than with other systems.

Data Conversion: The controller accepts the analog data and converts it to digital data using a specially designed, low-noise electronics supporting a scientific grade 12 bit Analog-to-Digital (A/D) converter.

Modular Design: In addition to containing the power supply, the controller contains the analog and digital electronics, scan control and exposure timing hardware, and controller I/O connectors, all mounted on user-accessible plug-in modules. The design is highly modularized for flexibility and convenient servicing.

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[*] An ST-133 5MHz controller must be factory configured for operation with an LN detector. For this reason, a detector purchased for operation with an LN detector can only be used with an LN detector. Similarly, a detector purchased for operation with a TE detector can ***not*** be used with an LN detector.

Flexible Readout: 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.

High Speed Data Transfer: Data is transferred directly to the host computer memory via a high-speed serial link. A frame buffer with standard composite video, either RS-170 (EIA) or CCIR, whichever was ordered, is also provided. The digital data at the output of the A/D converter is then transferred at high speeds to the host computer. A PCI Interface card places the data from the controller directly into the host computer RAM using Direct Memory Access (DMA). The DMA transfer process ensures that the data arrives at sufficiently high speed to prevent data loss from the controller. Since the data transfer rate is much higher than the output rate from the A/D, the latter becomes the data acquisition rate-limiting factor. Once the digital data is in RAM, the image acquisition program can transfer the image into its own working RAM for viewing and further processing.

Applications: With its small size, fully integrated design, cooled CCD and temperature control, advanced exposure control timing, and sophisticated readout capabilities, the ST-133 5MHz Controller is well suited to macro imaging and microscopy applications.

Chapter 2

Getting Started

Introduction

This chapter will help you get off to a good start with your ST-133 5MHz Controller. 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 switched on. Included are environmental, power, computer, and software requirements. Also provided are descriptions of the front and rear panels of the components, together with discussions of related topics such as mounting and imaging. Users are advised to read this chapter in its entirety before powering up the system.

Unpacking

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

Equipment and Parts Inventory

The complete system consists of a camera, a controller and other components as follows.

- Camera to Controller cable assembly: DB15 to DB15 and high-density DB40 to DB40.
- Controller to Computer cable: DB9 to DB9 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.
- System Dependent Interface Components:

Note: For convenience, in the following operating-procedure discussions, this manual refers to a PCI bus based PC equipped with a PCI high-speed interface card and using the Princeton Instrument’s WinView/32 software. Nevertheless, the manual does apply as well to operation with other computers and software. Interface components as follows could be required.

- High Speed PCI Interface Board (PC or Macintosh). This board must be installed in the computer (computers purchased from Roper Scientific will be shipped with the board already installed).

- Vacuum Pumpdown connector (2550-0181). This item is required when it becomes necessary to refresh the vacuum. *Contact the factory Technical Support for information on refreshing the vacuum. See page 76 for contact information.*

Grounding and Safety

The apparatus described in this manual is of 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 controller, 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 its safety has been verified by authorized personnel. Disconnecting the protective earth terminal, inside or outside the apparatus, or any tampering with its operation is also prohibited.

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

WARNING

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

Environmental Requirements

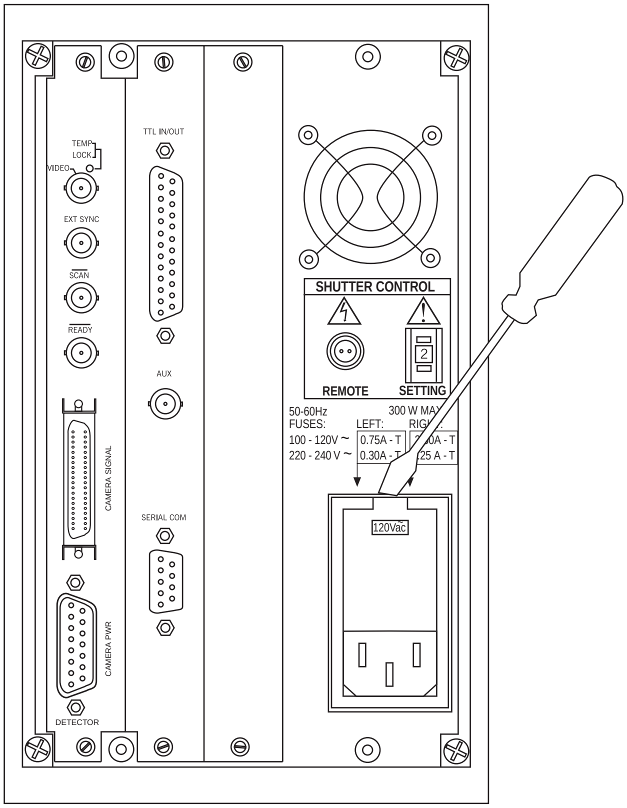
- Storage temperature -20°C to 55°C
- Operating environment 0°C to 30°C
- Relative humidity ≤50% noncondensing.

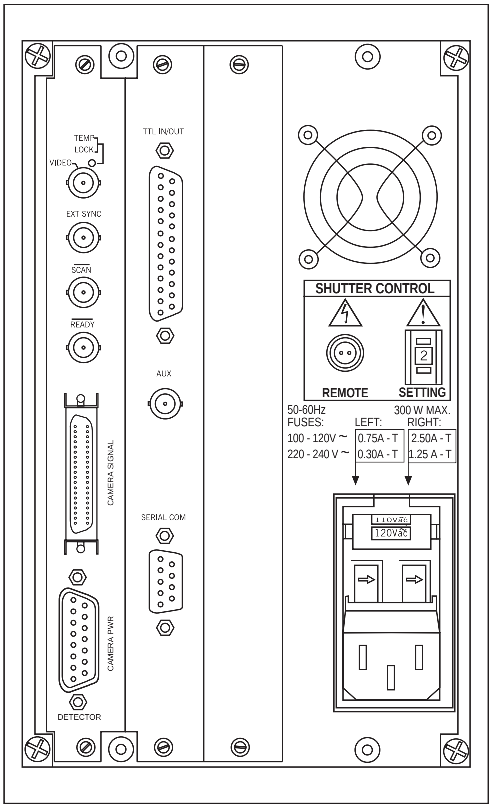
Power Requirements

The ST-133 5MHz controller can operate from any one of four different nominal line voltages: 100, 120, 220, or 240 V AC. The power consumption is 300 watts maximum (100 watts nominal) and the line frequency can range from 47 to 63 Hz.

The plug on the line cord supplied with the controller should be compatible with the line-voltage outlets in common use in the region to which the controller 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 2. Power Input Module.





The power module contains the voltage selector drum, fuses and the power cord connector. The appropriate voltage setting is set at the factory and can be seen on the back of the power module.

Each setting actually defines a range and you should select the setting that is closest to the actual line voltage. The fuse and power requirements are printed on the panel above the power module. As shown in Figure 2, the Power Module contains two fuses. The two fuses are of different values and both change according to the value of the selected line voltage as indicated on the back panel. The correct fuses for the country where the ST-133 5MHz is to be shipped are installed at the factory.

WARNING

Be sure to use the proper fuse values and types for the controller and camera to be properly protected.

To change the line-voltage setting or replace a fuse, proceed as follows.

WARNING

Before opening the power module, be sure to unplug the line cord.

- Take a flat blade screwdriver, place the flat side parallel to the back of the controller and pointing downward behind the small tab at the top of the power module, and twist the screwdriver slowly but firmly to pop the module open. *See Figure 2.*
- To change the voltage setting, roll the selector drum until the appropriate voltage setting is facing outwards.
- Confirm the fuse ratings by removing the white fuse holders. To do so, simply insert the flat blade of the screwdriver behind the front tab of each fuse holder and gently pry the assembly out.
- After inspecting and if necessary, changing the fuses, reinstall the holders with the arrow facing to the right.
- Close the power module and verify that the correct voltage setting is displayed.

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 the computer requirements. Please contact the factory to determine your specific needs.

PC

Type: Any Pentium (or better) PC having a free PCI slot.

Memory (RAM): Minimum of 32 Mbytes (64 Mbytes preferred); possibly more depending on experiment design and size of CCD Array.

Operating System: Windows 95 or NT.

Interface: PCI High-Speed Serial I/O card. *Computers purchased from Roper Scientific for use with the ST-133 MHz controller are shipped with the card installed.*

Computer Monitor: Super VGA monitor with 256 color graphics card and at least 512 kbytes of memory.

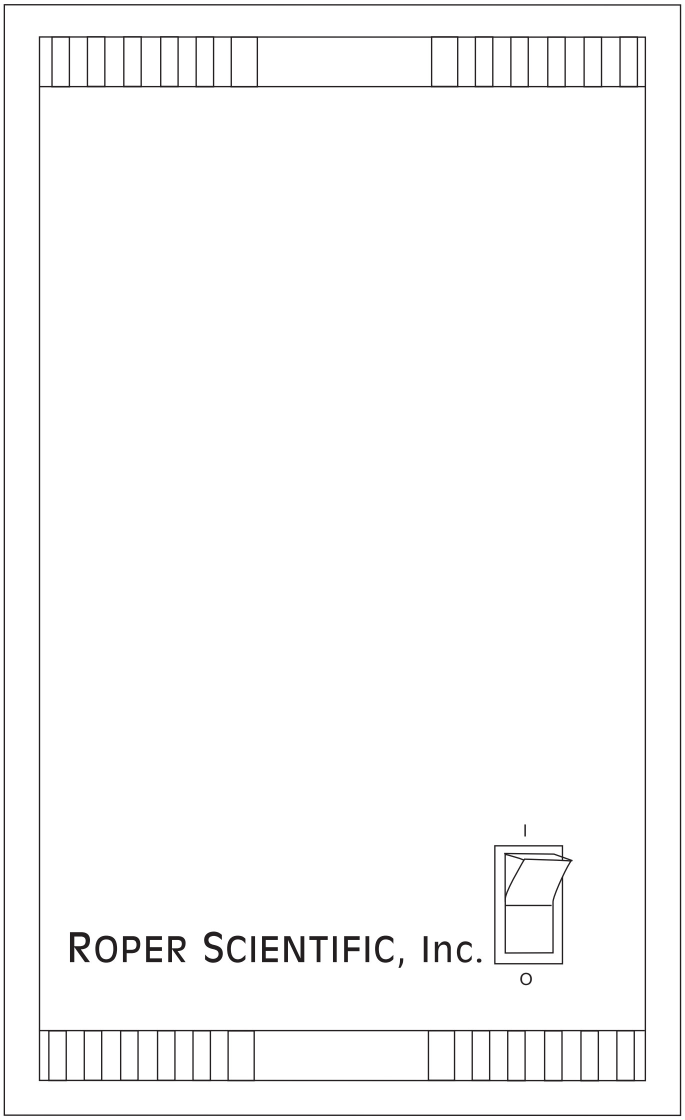
Mouse: Two-button Microsoft compatible serial mouse or Logitech three-button serial/bus mouse.

Controller Features

Front Panel

POWER Switch and Indicator: The power switch, which is located on the front panel as shown in Figure 3, interrupts both sides of the controller's AC power input. The switch's indicator LED lights whenever the ST-133 5MHz is powered. Note that, when the power switch is actuated, there is a short delay before the indicator lights. This is normal and in no way indicative of a malfunction.

Figure 3. ST-133 5MHz front panel.



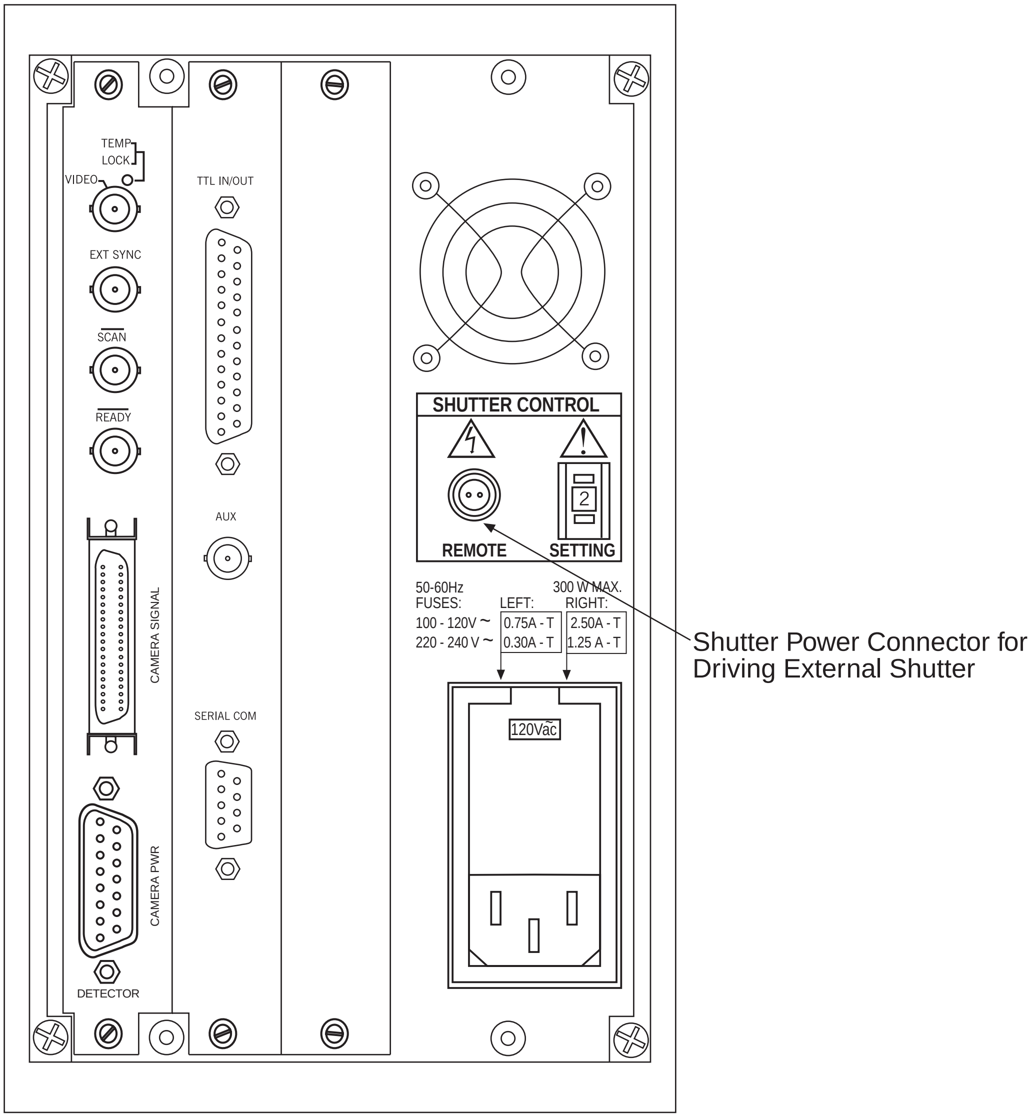


Figure 4. ST-133 5MHz back panel.

Back Panel

Fan: There is an internal fan located at the back panel behind the exhaust grill. Its purpose is simply to cool the controller electronics. This fan runs continuously whenever the controller is powered. Air enters the unit through ventilation slots on the sides and bottom, flows past the warm electronic components as it rises, and is drawn out the rear of the controller by the fan. It is important that there be an adequate air flow for proper functioning. As long as both the controller's intake ventilation slots and the fan aren't obstructed, the controller will remain quite cool.

Shutter Control: Directly below the fan are the Shutter Power connector and the Shutter Setting dial. The Shutter Power connector can be used to drive an external shutter if the camera isn't equipped with an internal shutter.

WARNING

If the camera is equipped with an internal shutter, then the Shutter Power connector should not be used to drive a second external shutter. This configuration will result in under-powering both shutters and may cause damage to the system. *In a system that requires both an internal and an external shutter, use the TTL Shutter Monitor signal (provided at the* $\overline{SCAN}$ *connector when selected by an internal jumper) to control the external shutter. Suitable driver electronics will additionally be required. Contact the factory Technical Support Dept. for information on changing the jumper setting.* *See page 76 for contact information.*

REMOTE: The shutter-drive pulses are provided at the **Remote** connector.

WARNING: Dangerous live potentials are present at the **Remote** Shutter Power connector. To avoid shock hazard, the Controller power should be OFF when connecting or disconnecting a remote shutter.

SETTING: The Shutter Setting selector sets the shutter drive voltage. Each shutter type, whether internal or external, requires a different setting. Consult the table below to determine the proper setting for your shutter. *The Shutter Setting dial is correctly set at the factory for the camera's internal shutter if one is present.*

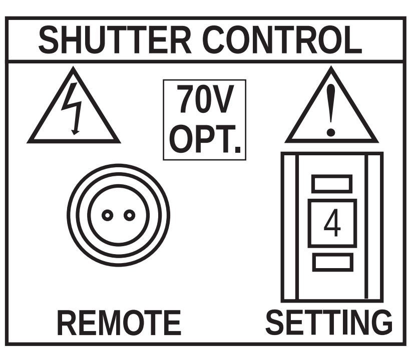
Table 1. Shutter drive selection.

1	External Shutter
5	Large Internal Shutter

WARNING

An incorrect setting may cause the shutter to malfunction or be damaged. Cameras having a 35 mm shutter, such as an NTE having the 1340 × 1300 CCD, must be used with an ST-133 having the 70 V shutter drive option installed (indicated on the back panel as shown in Figure 5). An ST-133 having this option cannot be used with a camera having the small (standard) shutter, even by selecting a lower number, because the shutter could be permanently damaged by the high drive voltage and larger stored energy required to drive the 70 V shutter.

Figure 5. Back panel of ST-133 having the 70 V shutter drive option.



Power Input Module: This assembly, located at the lower right of the controller back panel, has three functions.

- Connecting the AC power.
- Selecting the line voltage.
- Protective Fusing.

These functions are discussed in detail under *Power Requirements* on page 12.

Controller Modules: There are three controller board slots. Two are occupied by the plug in cards that provide various controller functions. The third, covered with a blank panel, is reserved for future development. The left-most plug-in card is the Analog/Control module. Adjacent to it is the Interface Control module. Both modules align with top and bottom tracks and mate with a passive back-plane via a 64-pin DIN connector. For proper operation, the location of the modules should not be changed. Each board is secured by two screws that additionally serve to ground each module's front panel. A detailed discussion of removing and inserting boards is provided in Appendix E, which begins on page 71.

WARNING

To minimize the risk of equipment damage, a module should ***never*** be removed or installed when the system is powered.

WARNING

If you should remove a module, take care not to overtighten the screws when you reinstall it. Use a screwdriver but be careful not to overtighten the screws. Excessive tightening could damage internal brackets.

Analog/Control Module: This module, which should always be located in the left-most slot, provides the following functions.

- Pixel A/D conversion
- CCD scan control
- Timing and synchronization of readouts
- Video output control
- Temperature control

In addition to the 15- and 40-pin connectors provided for the camera cable assembly, there are four BNC connectors and an LED, as discussed in the following paragraphs.

TEMP LOCK LED: This lights to indicate that the temperature of the CCD array is stable to within ± 0.05°C. The actual lower temperature limit that can be achieved will depend on a number of factors, including the laboratory temperature. Typical lower limit is -30°C at 25°C with a TEA detector head.

Note: There is provision in the hardware for reading out the array temperature at the computer. This temperature feedback display is very convenient for monitoring the temperature control status as it progresses towards temperature lock. To determine when lock occurs, however, use the Temperature Lock indication (LED or **locked** message displayed at the computer monitor. Note that it may take another 30 minutes after lock is reported before maximum stability is achieved.

VIDEO BNC connector: The composite video output is provided at this connector. 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 75 Ω coaxial cable and it must be terminated into 75 Ω. Many monitors have a switch to select either terminated or unterminated operation.

Note: If more than one device is connected to the video output, the ***last*** device is the one that should 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 the VCR to the 75Ω input of the monitor. Do *not* use a BNC TEE to connect the controller video output to multiple devices.

One of the limitations of scientific non-video rate cameras has been their difficulty in focusing and locating fields of view. The ST-133 5MHz solves this problem by its combination of high speed operation with the implementation of true video output. The high speed image update on the video monitor makes focusing and field location as simple as with a video camera. This video output also makes possible archiving an experiment on a VCR, producing hardcopy data on a video printer, or even implementing autofocusing stages.

The video output is selected by the Application software. In the case of WinView/32, this is done by selecting **Video** from the Acquisition menu. There is also provision in WinView/32 for intensity-scaling the video output by way of a hardware look-up table before display.

In addition to intensity-scaling, you also need to be concerned about how the array pixels map to the video display. In the case of a 1024×1024 array, the number of array pixels far exceeds the number of monitor pixels and mapping must be considered more carefully. WinView/32 software's **Video Focus** mode (accessed from the Acquisition Menu) provides a Pan function that allows any one of nine different subsets of the array image to be selected for viewing on the video monitor with only a single-frame delay. An associated zoom function provides 1x, 2x, or 4x viewing. At 1x, the entire array image is displayed, but at reduced resolution (pixels are discarded and fine detail could be lost). At 2x, the mapping is 1:1 and the image portion selected by the Pan function is provided. The regions overlap, allowing the entire array image to be examined with no loss of resolution. At 4x, array pixels are enlarged so that a smaller part of the array image is displayed as selected by the Pan function.

Once proper focus has been achieved, the user can transfer to normal data-acquisition operation. The video output remains operative, but with a more limited and fixed view because of the resolution limitation of RS-170 video. Although this view is sufficient to cover the image from a small CCD array in its entirety, it will not cover all the pixels from a large array. Instead, a subset from the center of the image will be shown. For example, in the case of a 1024x1024 array, the monitor would display the 756×486 area from the center of the CCD image as shown in Figure 6.

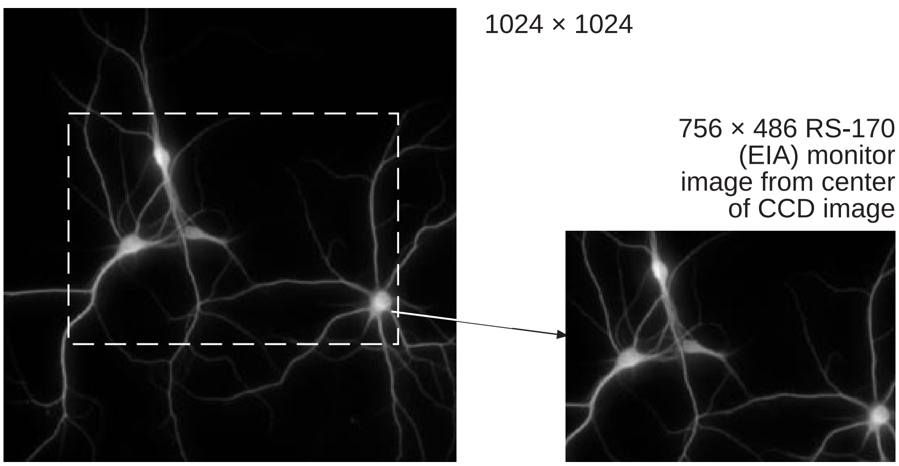


Figure 6. Monitor display of CCD image center area.

In post-acquisition processing the WinView/32 ROI (Region of Interest) capability allows any portion of an acquired image to be displayed on the computer monitor.

Again, note that the described video output behavior applies specifically for the WinView and WinView/32 software only. Other application software may provide different video output capabilities.

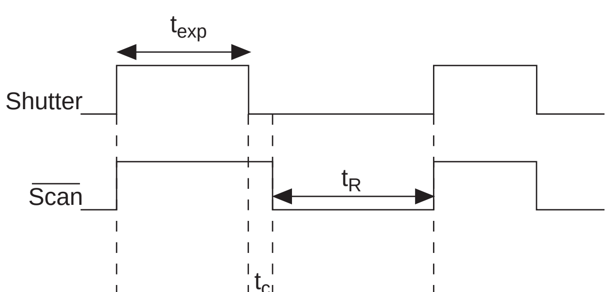
EXT SYNC BNC connector: This TTL input, which has a 10 kΩ pullup resistor, allows data acquisition to be synchronized with external events. Through software you can select either positive or negative edge triggering (default = negative). See *Chapter 6*, *Timing Modes* for detailed information.

$\overline{\text{SCAN}}$ BNC connector: Either of two signals, $\overline{\text{SCAN}}$ (NOTSCAN) or SHUTTER MONITOR, can be provided at this connector as determined by the setting of an internal jumper (default setting is SHUTTER MONITOR.) *Contact the factory Technical Support Dept. for information on changing the jumper setting. See page 76 for contact information.*

The first signal, $\overline{\text{SCAN}}$, reports when the controller is finished reading out the CCD array. $\overline{\text{SCAN}}$ is high when the CCD array is not being scanned, then drops low when readout begins, returning to high when the process is finished. The second signal, SHUTTER MONITOR, reports when the shutter is opened and can be used to synchronize external shutters. SHUTTER MONITOR is low when the shutter is closed and goes high when the shutter is activated, dropping low again after the shutter closes. As shown in Figure 7, except that the $\overline{\text{SCAN}}$ signal includes cleaning activity and t_c, the shutter compensation time (time allowed for the shutter to close), the two signals are similar.

Note: The ST-133 5MHz Controller does not include a shutter for interline and frame transfer CCD-based systems.

Figure 7. $\overline{\text{SCAN}}$ and SHUTTER MONITOR signals.



t_{exp} = Exposure Time

t_R = Readout Time

t_c = Shutter Compensation Time

Shutter Type	**Compensation Time**
Vincent (small)	8.0 msec
Prontor 40 (large)	28.0
Prontor 23 (external)	8.0
Intensified (electronic)	6.0
NONE	200 nsec

$\overline{\text{READY}}$ BNC connector: After a Start Acquisition command, this output changes state on completion of the array cleaning cycles that precede the *first* exposure. Initially high, it goes low to mark the beginning of the *first* exposure. In full-speed operation it remains low until the system is halted. If a specific number of frames have been programmed, it remains low until all have been taken, then returns high.

Detector Power connector: One of the two cables that interconnects the Controller and the Camera connects to this 15-pin connector (type DB15). This connector, the cable, and the corresponding connector on the camera are configured so that the cable cannot be installed incorrectly. Note that this cable has a sliding-latch locking mechanism at both ends. To ensure reliable operation, it is essential that both ends of the cable connector be secured before powering the system.

Note: When installing the cable assembly at the controller, the 15-pin Power connector must be installed before the 40-pin Signal connector. This sequence ensures the ground connection between the Controller and the Camera. If removing the cable assembly, this sequence is reversed.

Detector Signal connector: The second of the two cables that interconnects the Controller and the Camera connects to this high-density 40-pin D connector. This cable has a spring-latch locking mechanism at both ends. It is normally supplied attached to the Detector Power cable, forming a single cable assembly. To ensure reliable operation and avoid damage to the electronics, this cable should also be connected at both ends before powering the system.

WARNING

Always turn the power off at the Controller before connecting or disconnecting either of the cables that interconnect the camera and controller or serious damage to the CCD array may result. This damage is ***NOT*** covered by the manufacturer's warranty.

Interface Control Module: This module, which should always be located in the center slot, provides the following functions.

- TTL in/out Programmable Interface
- High speed serial communications control

TTL IN/OUT connector: This 25-pin connector (type DB25) provides a programmable interface. There are eight input bits and eight output bits that can be written to or polled to provide additional control or functionality. For the IN lines, a bit can be set to the buffered state, resulting in a real-time sample or it can be set to the latched state, where the signal is maintained once set. See Appendix B for a description of the pin assignments and refer to your software manual for calling conventions.

AUX BNC connector: Not currently activated. Reserved for future use.

SERIAL COM connector: The cable that goes to the computer connects to this DB9 connector. Its purpose is to provide two-way serial communication between the controller and the computer. When connecting this cable, 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 **Serial Com** connector with a short length of cable. Then the long-distance cable would be connected to the pod. *A similar fiber-optic pod connection would be required at the computer.*

See *Chapter 3, Installing the Computer Interface,* for detailed information on installing and testing the serial interface link.

CAUTION To minimize any possible risk to system equipment, we recommend that the serial link cable not be connected or disconnected when the system is powered.

Power Input Module: This module contains the line-cord socket, the Power On/Off switch and two fuses. The power requirements are printed on the panel above the module. For more detailed information, see *Power Requirements* on page 12.

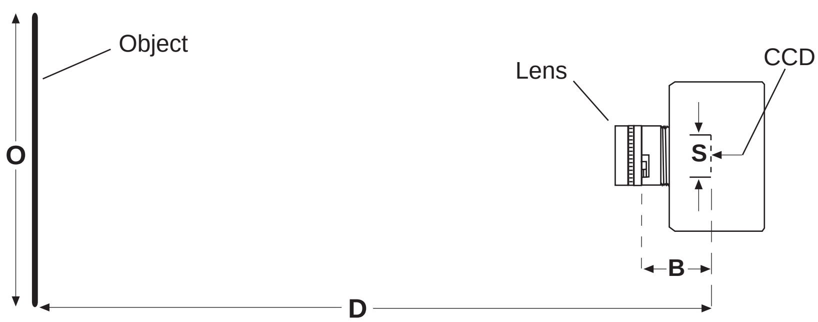
Software Installation

It is necessary to install the application software before the controller can be operated and data acquired. The installation procedure will vary according to the computer type, operating controller, and type of application software. See your software manual for detailed software installation and software-operation information.

Imaging Field of View

When used for two-dimensional imaging applications, a Princeton Instruments TE/CCD 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. The imaging field of view is indicated in Figure 8.

Figure 8. Imaging field of view.



D = distance between the object and the CCD

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

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

Summary

This completes *Getting Started*. You should now have a reasonable understanding of how the controller hardware is used. 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 controller.

Chapter 3

Installing the Computer Interface

Introduction

This chapter will lead you through the process of installing the Computer Interface. Following these steps explicitly will help insure proper connection to your computer.

PCI Serial Buffer Board

Introduction

If the computer is a PCI bus PC, it must be equipped with a PCI Serial Buffer board. Information about the installation and operation of this board follows.

CAUTION

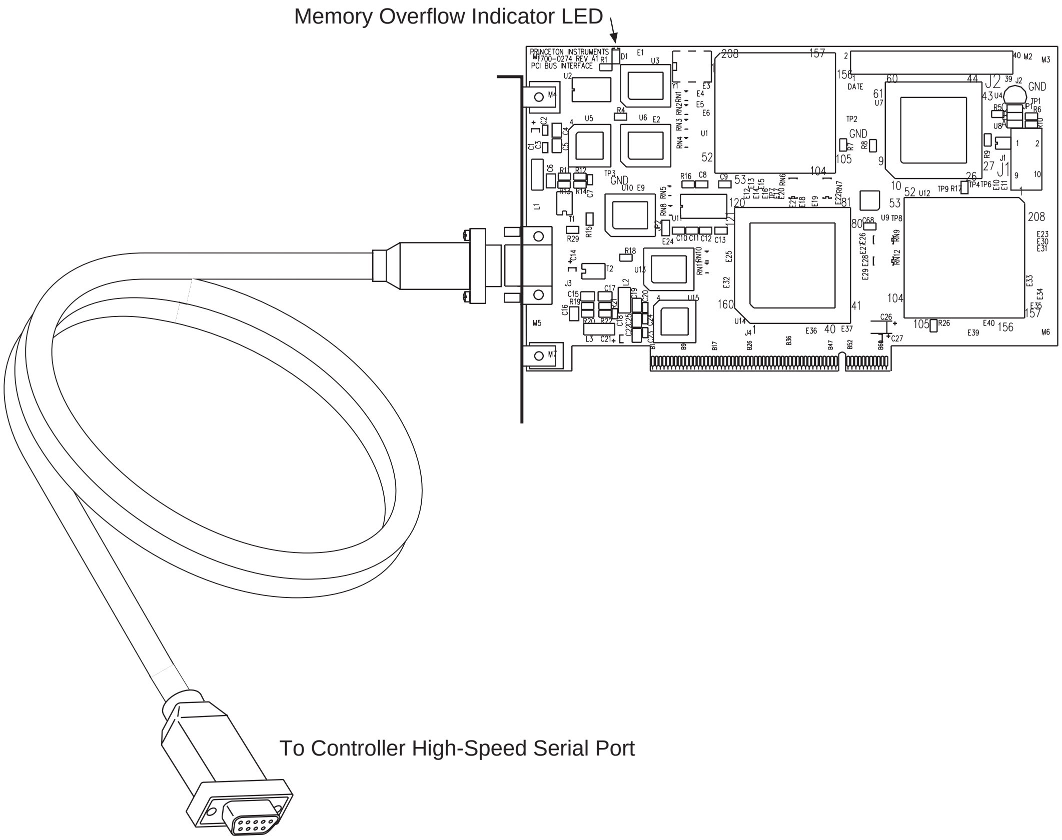
A PCI Serial board must be installed in an x86 type computer having a motherboard with at least one free PCI slot. The PCI Serial card must be plugged into a PCI slot. If using WinView/32 or WinSpec/32 software, **High Speed PCI** must be the selected Interface type (selection is accessed from **Hardware Setup** menu).

A screwdriver may be needed to remove screws from the computer (the type varies from computer to computer). A small, flat-bladed screwdriver is needed to connect both ends of the serial cable.

Installing the PCI Card

- Remove the expansion slot cover on the rear panel of the I/O slot selected *(see Figure 10)*.
- Insert the PCI Serial Interface card as far as possible into the appropriate PCI socket (Figure 11). Then secure the Serial Buffer Board by reinstalling the expansion slot cover screw.

Figure 9. PCI serial board.



Connect the standards TAXI* serial cable to the nine-pin cable connector on the PCI Serial Buffer Board mounting panel as shown in Figure 9. The other end of the serial cable connects to the Controller's high-speed serial output connector. Take care to tighten the screws at both ends of the cable using a small, flat-bladed screwdriver.

* TAXI is a registered trademark of AMD Corporation.

Figure 10. Removing the expansion slot cover on an AT type computer.

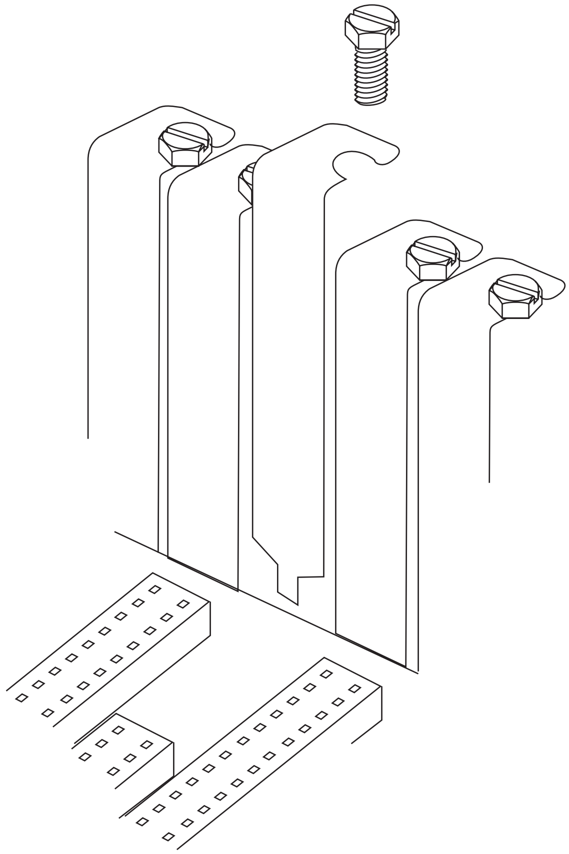
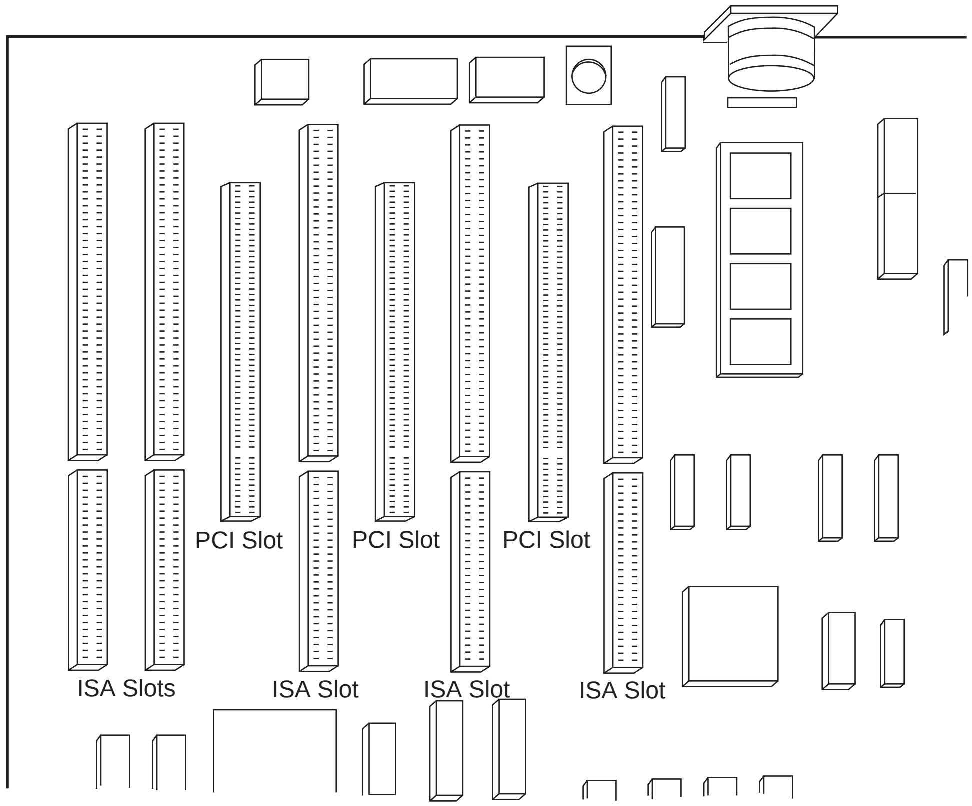


Figure 11. PCI expansion slots in typical computer.



Power-On Checks

Introduction

Before proceeding, be sure the PCI Serial Buffer Board is firmly mounted in the slot. Replace the cover of the computer and turn on the computer only. If an error occurs at bootup, either the PCI serial card was not installed properly or there is an address or interrupt conflict.

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 does not 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.

I/O Address & Interrupt Assignments
Before Installing Serial Card

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

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.

I/O Address & Interrupt Assignments
After Installing Serial Card

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 PCI Serial Card	FF80-FFFF	15

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 does not 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 Roper Scientific's 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 if using 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.

Apple Macintosh

Apple Corp. has adopted the PCI bus standard for Macintosh computers. As a result, the PCI card can be installed and operated in a Macintosh running IPLab software and the PI Extension. Contact the factory for additional information.

Chapter 4
First Light

Introduction to Imaging

This section provides step-by-step instructions for making an imaging measurement.

At this point a lens should be mounted on the camera or the camera mounted on a microscope. *See your camera manual for lens and camera mounting instructions.* A suggested procedure for operating the system and viewing your first images follows. Note that the intent of this simple procedure is to help you gain basic familiarity with the operation of your ST-133 5MHz based system 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 6, *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 much easier with a video monitor because the displayed data is updated much 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

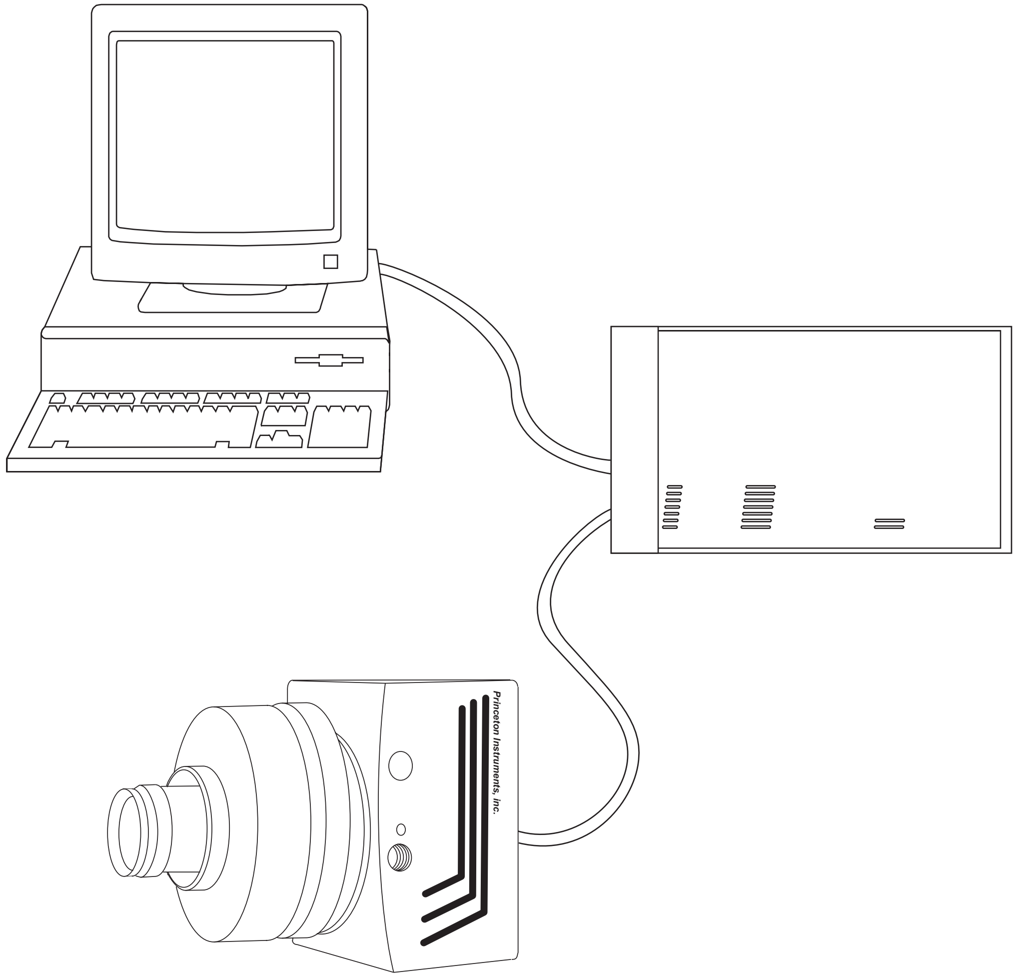
Before You Start, if your system includes a microscope Xenon or Hg arc lamp, it is **CRITICAL** to turn off all electronics adjacent to the arc lamp, especially your digital camera system and your computer hardware (monitors included) before turning on the lamp power.

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 Roper Scientific 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. *Therefore, in order to fully guarantee the performance of your system, you must follow this startup procedure.*

Procedure

- If the system cables haven't as yet been installed, connect them as follows (system power off). *See Figure 12.*
- Connect the 15-pin and 40-pin connectors of the controller-to-camera cable assembly from the connectors on the Analog/Control module panel to the mating connectors at the back of the camera. Be sure to secure the 15-pin connectors at both ends with the slide-lock latch and the 40-pin connectors with the spring-loaded latch.

Figure 12. System connection diagram.



- Connect one end of the 9-pin serial cable to the **SERIAL COM** connector on the Interface Control module panel. Connect the other end to the computer interface as described in Chapter 3. Be sure to secure both ends of the cable with the cable-connector screws.
- 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.
- Connect the line cord from the Power Input assembly on the back of the controller to a suitable source of AC power.
- If you haven't already done so, install a lens on the camera. The initial lens settings aren't important but it may prove convenient to set the focus to approximately the anticipated distance and to begin with a small aperture setting.
- Turn on the system power. *The Power On/Off switch is located on the front of the controller.* The **POWER** light at the front panel of the Power Supply should light after a few seconds.
- Turn on the power at the computer and start the application software (WinView/32, for example if the computer is a PCI bus PC).

- Set up the applications software for a temperature of -30°C for TEA cameras. The temperature should drop steadily, reaching -30C° in about thirty minutes (typical). At that point the green **Temp Lock** LED on the Analog/Control module will light and there will be a **locked** indication at the computer monitor, indicating that temperature lock has been established. Note that some overshoot may occur. This could cause temperature lock to be briefly lost and then quickly re-established. If you are reading the actual temperature reported by the application software, note that the display has only 0.5°C increments. There may be a small difference between the set and reported temperature when lock is established. This is normal and does not indicate a system malfunction.

- At the computer, set up the applications software for your hardware setup. In WinView/32 the Hardware Setup dialog box is selected from the initial screen. Be sure to activate the video output by clicking on **Video** on the Acquisition menu. *See your application software manual for detailed information.*

- If using WinView/32, select the **Video Focus** mode from the Acquisition menu. Then select a short exposure time (0.1 s), an Intensity Scaling setting of Gamma, and 2x Zoom. With a camera with higher than 756x486 pixel resolution , set the Pan selector as required for the 756×486 subset of the array image you wish to use for focusing purposes.

- Begin data collection by selecting RUN on the **Video Focus** dialog box. The shutter, if present, will open and successive images will be sent to the monitor as quickly as they are acquired, giving as close to continuous video as possible.

  Note: Because the time to acquire and read out an image varies directly with the size of the CCD, the observed frame rate will vary greatly depending on the CCD installed. With a short exposure time, it is not uncommon for the frame readout time to be significantly longer than the exposure time.

- Adjust the lens aperture, intensity scaling, and focus for the best image as viewed on the video monitor. Some imaging tips follow.

  - Begin with the lens blocked off. Set the lens at the smallest possible aperture (largest f-stop number).

  - Place a suitable target in front of the lens. An object with text or graphics works best. If working with a microscope, use any easily viewed specimen. It is generally not advisable to attempt fluorescence imaging during this *Getting Started* phase of operation.

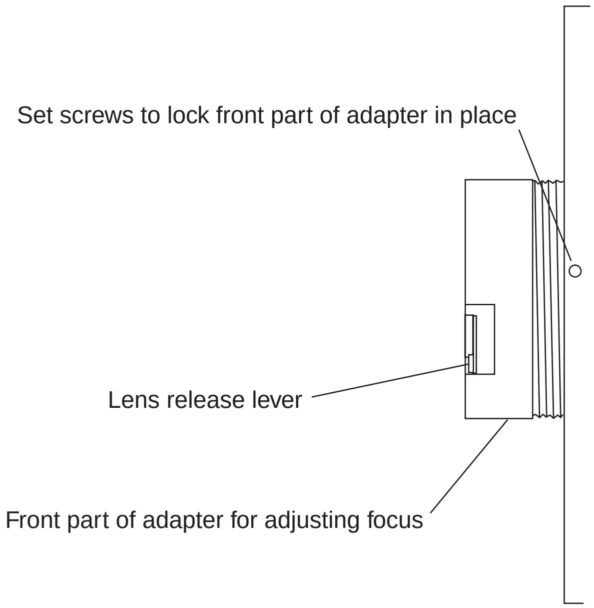
  - Adjust the intensity scaling and lens aperture until a suitable setting is found. The initial intensity scaling setting of Gamma assures that the image won’t be missed. Once you’ve determined that the image is present, select a lower, linear setting for better contrast. Check the brightest regions of the image to determine if the A/D converter is at full-scale. *The A/D converter is at full-scale when any part of the image is as bright as it can be.* Adjust the aperture to where it is just slightly smaller (higher f stop) than the setting where maximum brightness on any part of the image occurs.

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

- In the case of a camera with an F-mount, the adapter itself also has a focus adjustment. If necessary, this focus can be changed to bring the image into range of the lens focus adjustment. The lens-mount adjustment is secured by four set screws as shown in Figure 13. To change the focus setting, proceed as follows.

- Loosen the set screws with a 0.050" Allen wrench. Do not remove the screws; loosen them just enough to allow the lens mount to be adjusted.
- Rotate the lens mount as required to bring the focus within range of the lens focus adjustment.
- Tighten the set screws loosened above.

Figure 13.
F-mount focus adjustment.



➧ Once optimum focus and aperture have been achieved, you can switch from **Video Focus** mode (WinView/32) to standard data-acquisition operation. (In WinView/32 you might want to begin with Free-Run Safe-Mode operation while gaining basic system familiarity.)

Summary

This completes *First Light*. If the system functioned as described, you can be reasonably sure it has arrived in good working order. In addition, you should have a basic understanding of how the system hardware is used. 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.

Chapter 5

Temperature Control

Introduction

The CCD temperature setting is done via software. Once the desired array temperature has been set, the software programs the thermoelectric cooling circuits in the camera and these circuits reduce the array temperature to the set value. On reaching that temperature, the control loop locks to the set temperature for stable and reproducible performance. The green **TEMP LOCK** indicator on the Analog/Control module panel lights to indicate that temperature lock has been reached (temperature stable to within ±0.05°C). There is also a **TEMP LOCK** indication at the computer monitor. This on-screen indication allows easy verification of temperature lock in experiments where the computer and controller are widely separated. There is also provision for reading out the actual temperature at the computer so that the progress of the cooling can be monitored.

Because the control loop is designed to achieve temperature lock as quickly as possible, overshoot may occur. If this happens, temperature lock will be briefly indicated and then discontinue during the overshoot. However, the lock indication will be quickly restored as stable control is re-established. This is normal behavior and should not be a cause for concern. Should a low temperature be set initially and then a higher one, this overshoot would probably not occur because the temperature control loop does not drive the temperature higher, but rather waits passively for temperature rise to occur. The achievable temperature is influenced by the type of CCD array installed. Optimum noise performance is achieved by operating at the lowest temperature at which temperature lock can be maintained. Typically, the lowest temperature achievable is approximately -30°C with the camera under vacuum.

With thermoelectric cooling, at an ambient temperature of 25°C, temperature lock at -30°C should typically take about thirty minutes. Note that cooling performance is affected by the CCD array being used. Also, if the lab is particularly warm, achieving temperature lock might take a little longer, or the lowest temperature at which lock can be achieved could be a little higher. Once lock occurs, we recommend that you wait another fifteen or twenty minutes before taking data. This additional time is required to achieve optimum thermal stability.

Cooling

TE/CCD cameras are equipped with a solid-state thermoelectric (TE) heat removal system. Central to this system is a multi-stage Peltier type cooler that is thermally coupled to the CCD surface. This device uses injected current to draw heat away from the CCD surface. The heat is sequentially transferred through the Peltier stages and is then coupled to the outer shell of the camera via a heat transfer block. A fan on the back panel of the camera exhausts this heat to the surrounding atmosphere. In addition, fins on the camera shell radiate the heat outward.

Cooling and Vacuum

There can be a gradual lessening of the camera's vacuum with time. This in turn can affect temperature performance to where it may no longer be possible to achieve temperature lock at the lowest temperatures. In the kind of low-light imaging applications for which cooled CCD cameras are so well suited, it is highly desirable to maintain the system's temperature performance because the lower the temperature, the lower the thermal noise will be and the better the signal-to-noise ratio.

Vacuum deterioration occurs primarily as a result of outgassing occurring in the vacuum chamber and normally diminishes with time. As a result, a camera that has to be repumped after perhaps a year of operation may not have to be pumped again for several years. In any case, should you notice a gradual deterioration in temperature control performance indicative of vacuum deterioration, the camera can be repumped. *Contact the factory Technical Support for information on refreshing the vacuum.* *See page 76 for contact information.*

WARNING The CCD array is subject to damage from condensation if exposed to the atmosphere when cold. For this reason, the camera should be kept properly evacuated.

Problems

If it should happen that temperature lock cannot be achieved or maintained, it will be necessary to find and correct the problem to be assured of good measurement results. Possible causes could include:

- The vacuum has deteriorated as described above and needs to be repumped.
- The slide-lock latches on the Power connector of the cable that interconnects the controller and the camera need to be secured.
- The internal temperature of the camera has gotten too high, such as might occur if the operating environment is particularly warm or if you are attempting to operate at a temperature colder than the specified limit. If the heat-transfer block temperature exceeds 50°C, an internal thermo-cutout switch will disable the cooler circuits to protect them. Typically, camera operation is restored in about ten minutes. Although the thermo-cutout switch will protect the camera, users are advised to power down and correct the operating conditions that caused the thermal-overload to occur.

Chapter 6
Timing Modes

The Princeton Instruments ST-133 5MHz Controller has been designed to allow the greatest possible flexibility when synchronizing data collection with an experiment.

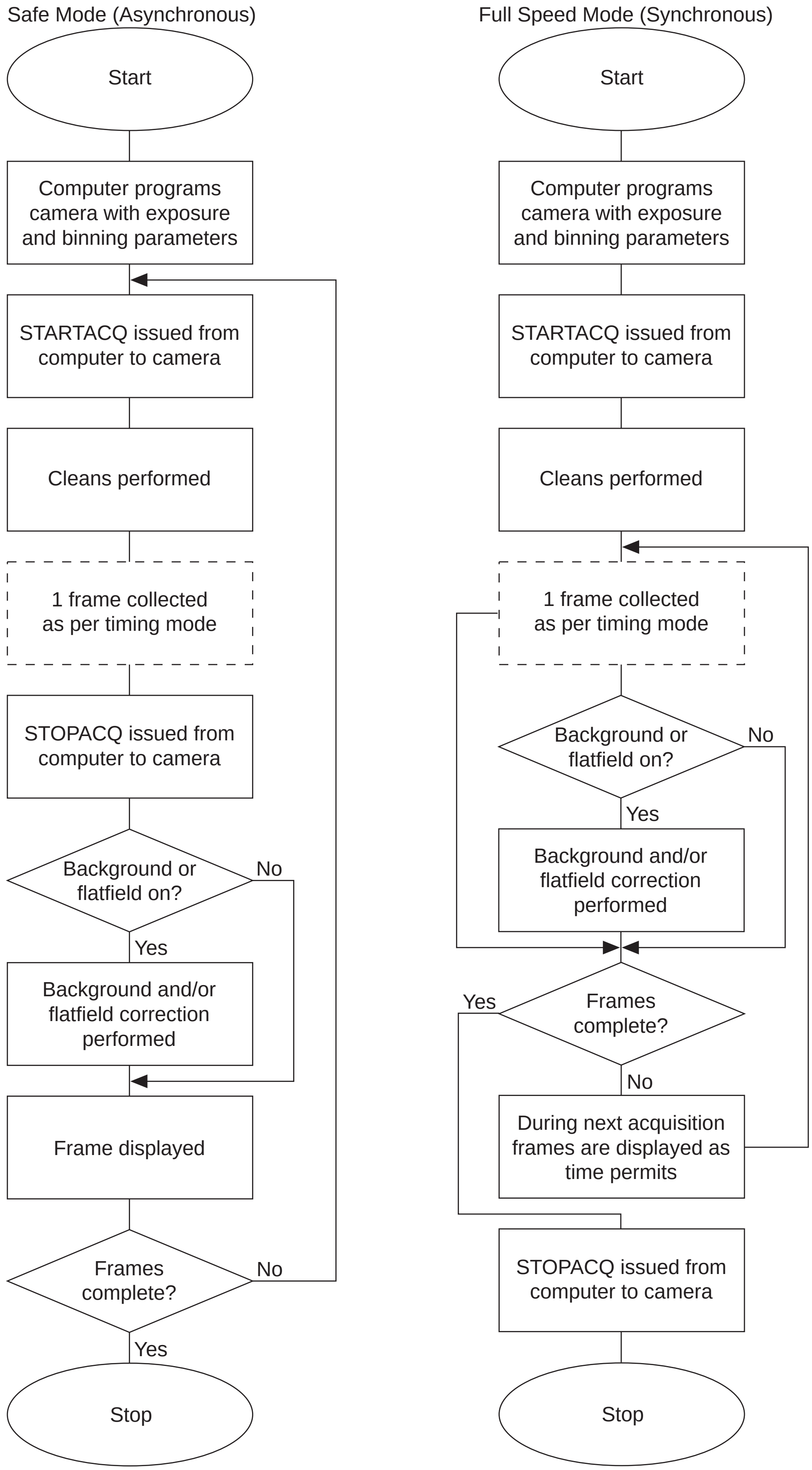
Full Speed or Safe Mode

The WinView/32 Experiment Setup **Timing** tab page allows the user to choose **Safe Mode** (formerly known as Asynchronous) or **Full Speed** (formerly known as Synchronous). Figure 14 is a flow chart comparing the two modes. In Safe Mode operation, the computer processes each frame as it is received: the ST-133 5MHz cannot collect the next frame until the previous frame has been completely processed. In Full Speed operation, the ST-133 5MHz runs according to the timing of the experiment, with no interruptions from the computer.

Safe Mode operation 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. As seen in Figure 14, in Safe Mode operation, the computer controls when each frame is taken. After each frame is received, the camera sends the Stop Acquisition command to the camera, instructing it to stop acquisition. Once that frame is completely processed and displayed, another Start Acquisition command 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 ST-133 5MHz is disabled for a short time after each frame.

Full Speed operation is primarily for collecting “real-time” sequences of experimental data, where timing is critical and events cannot be missed. Once the ST-133 5MHz is sent the Start Acquisition command (STARTACQ) by 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.

Figure 14. Chart of Safe Mode and Full-Speed operation.



Standard Timing Modes

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

Table 2. Camera timing modes.

Timing Mode	Shutter Control	Continuous Cleans	Pre Open
Free Run	Normal	N/A	N/A
	Disabled Closed	N/A	N/A
	Disabled Open	N/A	N/A
External Sync	Normal	Selectable	Selectable
	Disabled Closed	Selectable	N/A
	Disabled Open	Selectable	N/A

The basic ST-133 5MHz timing modes are Free Run and External Sync. These timing modes are combined with Shutter Control choices and checkbox options (see *Table 2*) to provide the widest variety of timing modes for precision experiment synchronization.

Note: If using the WinView/32 software, these selections are accessed from the Experiment Setup Timing tab page.

The shutter options available include Normal, 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.

The two checkbox options available only in the External Sync mode are Continuous Cleans and Pre Open. Continuous Cleans (when selected) is used to prevent the buildup of dark charge while the camera is waiting for the External Sync pulse. Pre Open (when selected) opens the shutter as soon as the ST-133 5MHz controller is ready to receive an External Sync pulse. This is required if the time between the External Sync pulse and the event is less than a few milliseconds, the time it takes the shutter to open.

The shutter timing is shown in the timing diagrams that follow. Except for Free Run, 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). See Chapter 7 for additional information.

Free Run timing

In the **Free Run** mode (Full-Speed operation) the controller does not synchronize with the experiment in any way. The shutter opens as soon as the previous readout is complete (non-overlapped mode), 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.

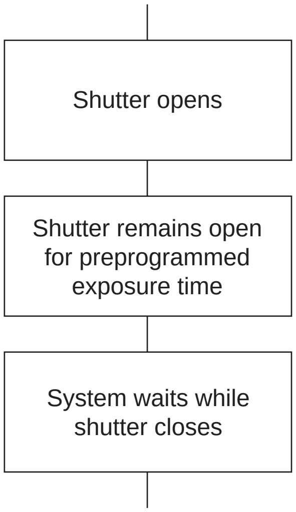


Figure 15. Free Run timing chart, part of the chart in Figure 14.

Other experimental equipment can be synchronized to the ST-133 5MHz controller by using the $\overline{\text{SCAN}}$ (NOTSCAN) signal. This TTL output for synchronous operation is shown in Figure 16.

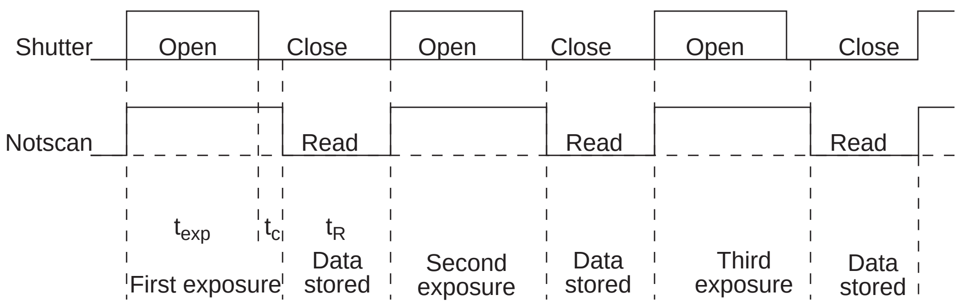


Figure 16. Free Run timing diagram.

External Sync timing

In this mode all exposures are synchronized to an external source by means of a TTL transition at the Analog Control module **Ext Sync** connector. As shown in the flow chart, Figure 17, this mode can be used in combination with Normal or Pre Open Shutter operation. In Normal Shutter mode, the controller waits for an External Sync pulse, then opens the shutter for the programmed exposure period. As soon as the exposure is complete, the shutter closes and the CCD array is read out. The shutter requires 5-10 msec to open completely, depending on the model of shutter. (Shutter compensation time is discussed in Chapter 7.)

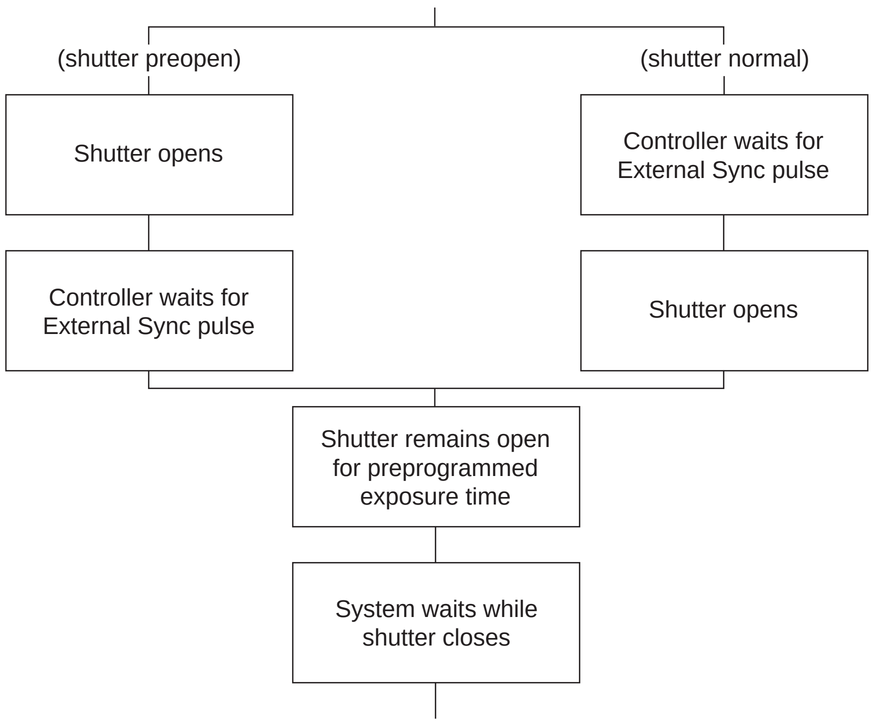
Since the shutter requires up to 10 msec to fully open, the External Sync pulse provided by the experiment must precede the actual signal by at least that much time. If not, the shutter will not be open for the duration of the entire signal, or the signal may be missed completely.

Also, since the amount of time from 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.

In the Pre Open Shutter mode, on the other hand, shutter operation is only partially synchronized to the experiment. As soon as the controller is ready to collect data the shutter opens. Upon arrival of the first External Sync pulse at the ST-133 5MHz controller, 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.

Note: If EXT SYNC is still active at the end of the readout, the hardware will interpret this as a second sync pulse, and so on.

Figure 17. Chart showing two External Sync timing options.

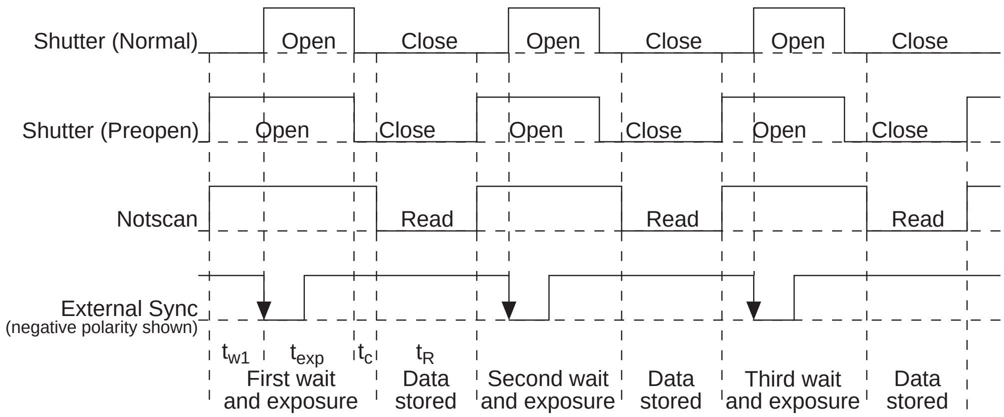


The PreOpen mode is useful in cases where an External Sync pulse cannot be provided 5-10 msec before the actual signal occurs. Its main drawback is that the CCD is exposed to any ambient light while the shutter is open between frames. If this ambient light is constant, and the triggers occur at regular intervals, this background can also be subtracted, providing that it does not saturate the CCD. As with the Normal Shutter mode, accurate background subtraction may not be possible for the first frame.

Also note that, in addition to signal from ambient light, dark charge accumulates during the “wait” time (t_w). Any variation in the external sync frequency also affects the amount of dark charge, even if light is not falling on the CCD during this time.

Note: With the WinView/32 software, the Ext Sync timing mode must be selected before the Continuous Cleans selection becomes available.

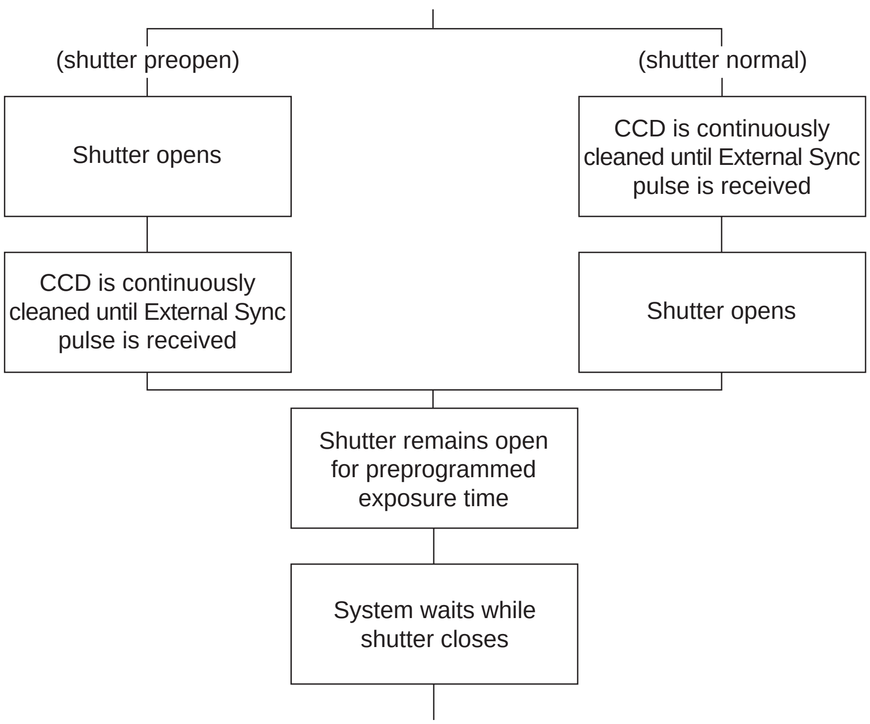
Figure 18. Timing diagram for the External Sync mode.



External Sync with Continuous Cleans Timing

The Continuous Cleans choice, available after External Sync has been selected, is in addition to the standard "cleaning" of the array, which occurs after the controller is enabled. Continuous Cleans will remove any charge from the array until the moment the External Sync pulse is received.

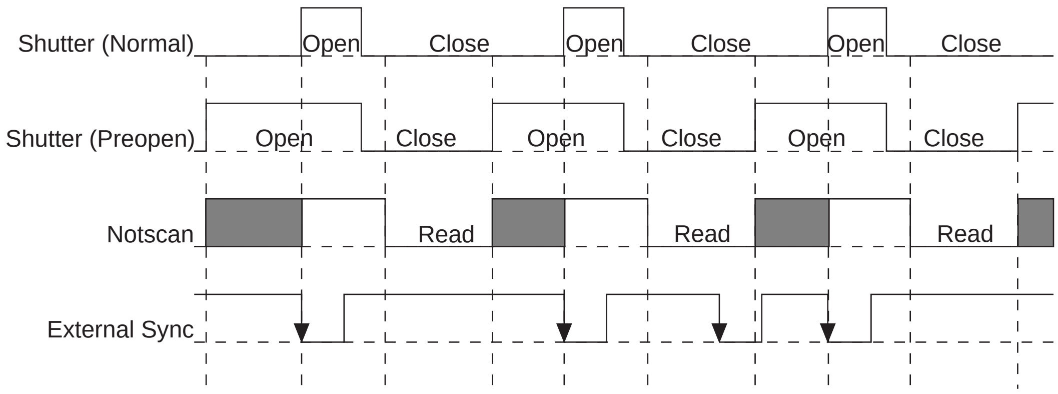
Figure 19. Continuous Cleans operation flow chart.



Once the External Sync pulse is received, cleaning of the array stops as soon as the current clean cycle is complete, and frame collection begins. With Normal Shutter operation, the shutter is opened for the set exposure time. With Pre Open 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, then closes. If the clean cycle is incomplete when the External Sync pulse arrives, the pulse is saved until the clean cycle 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 photo generated electrons are still collected over the entire active area. However, if the signal arrival is coincident with the vertical shifting, image smearing of up to one pixel is possible. The amount of smearing is a function of the signal duration compared to the single vertical shift time.

Note: If EXT SYNC is still active at the end of the readout, the hardware will interpret this as a second sync pulse, and so on.

Figure 20. Continuous Cleans timing diagram.



Frame Transfer Mode

In 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 7 for a detailed discussion of readout in the frame-transfer mode operation; the primary focus of this section is frame-transfer timing.*

There are two timing options available in frame transfer mode, Free Run and External Sync. Both 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. The *actual exposure time* is the time between data 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}. Data 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 data is shifted to the array's output port, the same as in standard operation.

In Free Run frame-transfer mode operation, half the array is exposed for the set exposure time (t_{exp}). Then the data transfer to the storage half of the array takes place, marking the start of the read and the beginning of a new exposure.

In External Sync frame-transfer mode operation, the camera reads out one frame for every External Sync pulse received, providing the frequency of the External Sync pulse doesn't exceed the maximum rate possible with the system. Other than for the first readout, initiated by starting acquisition, a Sync Pulse must be detected before the subsequent readout can occur. If operating without a shutter, the actual exposure time is set by the period of the sync signal. There is one exception, if the programmed exposure time is less than the readout time, then the actual exposure time is simply equal to t_R, the readout time (marked by $\overline{\text{SCAN}}$ low). More specifically, if the readout time, t_R, is greater than the sum of t_{w1}, the time the controller waits for the first External Sync pulse, plus t_{exp}, the programmed exposure time, plus t_c, the shutter compensation time, then the actual exposure time will equal t_R. If an External Sync pulse is detected during each read, frames will follow one another as rapidly as possible as shown in Figure 21. *In these figures, Shutter Monitor indicates the programmed exposure time. If a shutter were present and active, it would also be the actual exposure time.*

Prior to the first readout, clean cycles are performed on the array. When the software issues a Start Acquisition command, the first readout is generated in hardware and the rapid data transfer from the exposure half of the array to the storage half of the array occurs (marking the beginning of the first exposure). The initial data read are discarded because they are not meaningful. The first exposure continues until the next data transfer, which occurs at the beginning of the next readout, 50 ns after the first readout ends. The data acquired during the first exposure is then read out. This pattern continues for the duration of the experiment so that, during each frame, the data acquired during the previous frame is read out.

Figure 21. Frame Transfer where $t_{w1} + t_{exp} + t_c < t_R$.

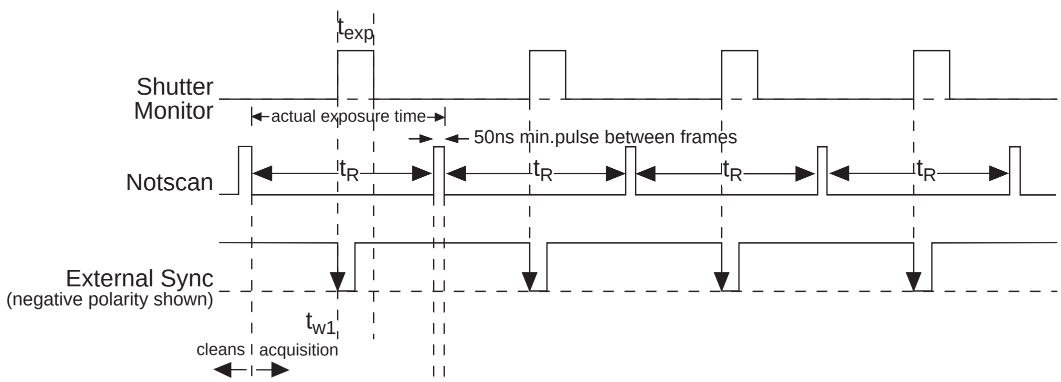


Figure 22 shows the case where the programmed storage time is greater than the time required to read out the storage half of the array, that is, where $t_{w1} + t_{exp} + t_c > t_R$. In this case, the programmed exposure time will dominate in determining the actual exposure time. In the situation depicted in Figure 22, the External Sync pulse arrives during the readout. As always, the External Sync pulse must be detected before the next readout can occur. However, there is no requirement as to when it must be applied or even that it be periodic. The timing of the External Sync pulse is entirely at the user's discretion. In Figure 23, the External Sync pulse is shown arriving after the read. Detection of the External Sync pulse enables a new readout to occur on completion $t_{exp} + t_c$.

Figure 22. Frame Transfer where t_{w1} + t_{exp} + t_c > t_R.

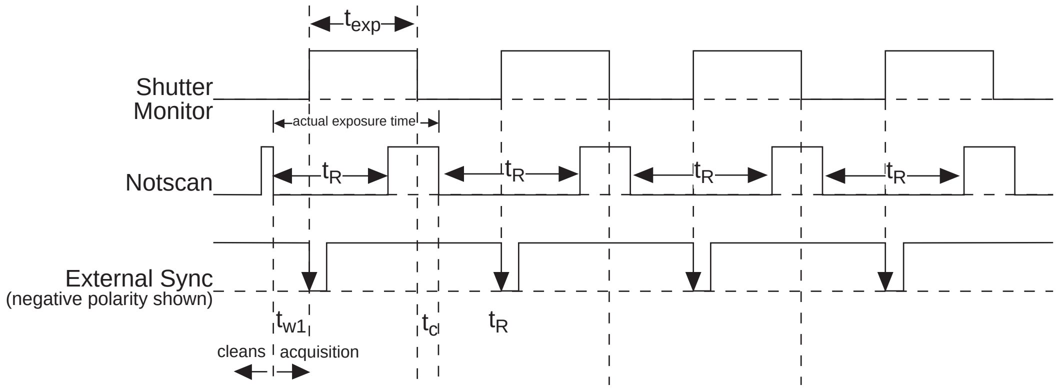
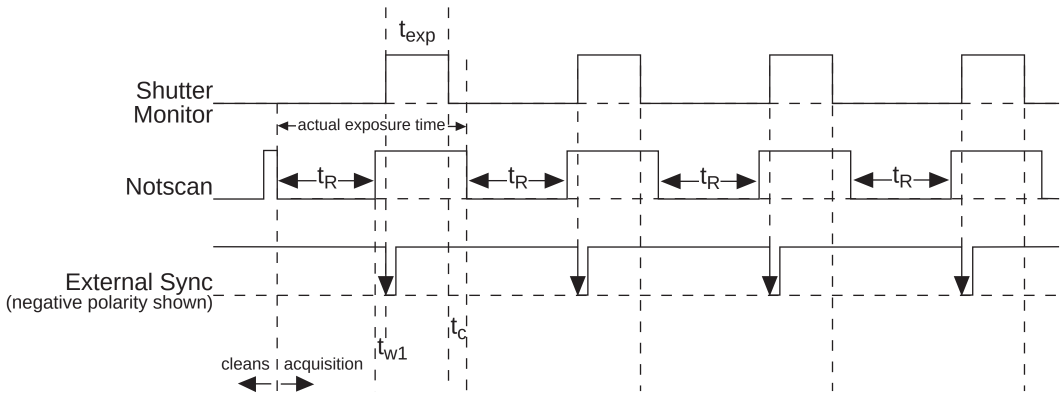


Figure 23. Frame Transfer where pulse arrives after readout.



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Chapter 7
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. Figure 24 is a block diagram of the image-signal path.

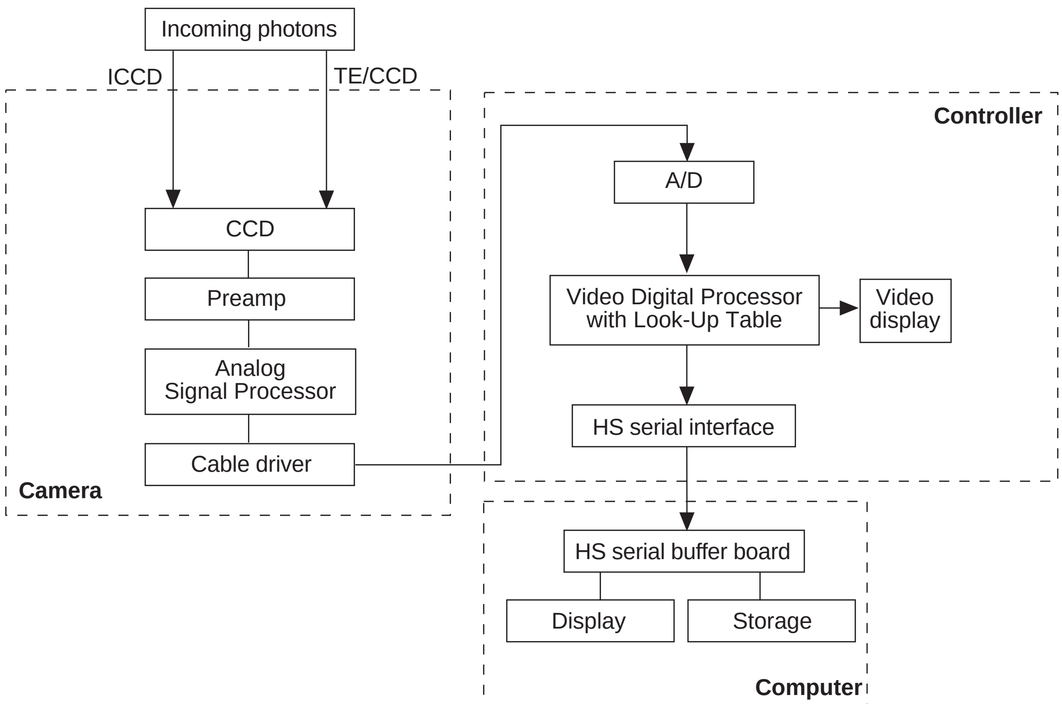


Figure 24. Block diagram of light path in system.

The remainder of this chapter describes the exposure, readout, and digitization of the image. Included are descriptions of binning for imaging applications and the specialized ST-133 5MHz timing modes.

Exposure

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, magnetic fields and RF radiation. They are easily cooled and can be precisely thermostated to within a few tens of millidegrees.

Because CCD arrays, like film and other media, are always sensitive to light, many CCD cameras must be equipped with a shutter or a image intensifier to prevent light from falling on the array during readout. However, unintensified frame transfer CCD cameras may be operated with or without a shutter, depending on whether or not some image smearing is acceptable during the transfer.

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. During each scan, the shutter or intensifier is enabled for the duration of the exposure period, allowing the pixels to register light.

Exposure with a mechanical shutter

For some CCD arrays, the ST-133 5MHz uses a mechanical shutter to control exposure of the CCD. The diagram in Figure 25 shows how the exposure period is measured. The $\overline{\text{SCAN}}$ output provided at the ST-133 Analog/Control panel can be used to monitor the exposure and readout cycle (t_R). This signal is also shown in Figure 25. The value of t_c is shutter type dependent, and will be configured automatically for ST-133 5MHz controllers shipped with an internal shutter.

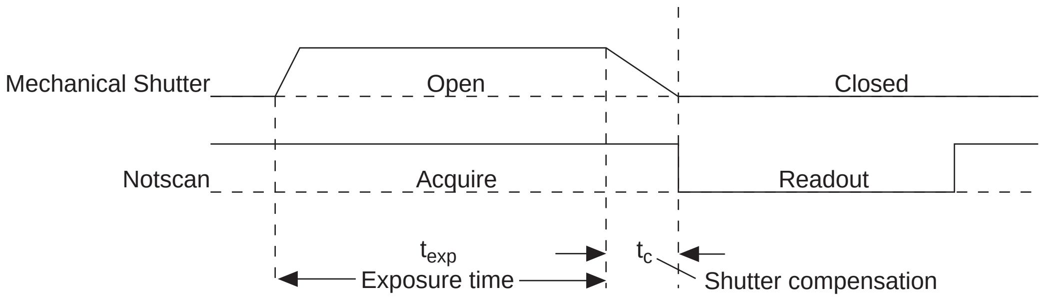


Figure 25. Exposure of the CCD with shutter compensation.

$\overline{\text{SCAN}}$ is low during readout, high during exposure, and high during shutter compensation time.

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

Exposure with an image intensifier

Although the standard ST-133 5MHz camera is not intensified, it is possible to connect it to a lens coupled intensifier, making the following general discussion of intensified operation applicable.

ICCD (intensified) cameras use an image intensifier both to gate light on and off and to greatly increase the brightness of the image. In these cameras the image intensifier detects and amplifies the light, and the CCD is used for readout.

The exposure programmed by software in this case refers to duration of gating of the intensifier. For shorter exposures, a Princeton Instruments pulser is required.

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 Roper Scientific have the lowest EBI values possible.

Continuous exposure (no shuttering)

Cameras with frame-transfer capability may be used with or without a shutter. When operating without a shutter, image smearing may occur, depending on the exact nature of the experiment. This effect, caused by light falling on the CCD array as the charge is shifted to the masked area, occurs only if the CCD is illuminated during shifting. In the case of intensified cameras (ICCDs), this effect can be eliminated by using a fast phosphor and gating the intensifier at the same frame rate as the CCD.

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.

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 (Signal-to-Noise ratio) accomplished through the software.

For signal levels low enough to be readout-noise limited, longer exposure times, and therefore longer signal accumulation in the CCD, will improve the S/N ratio approximately linearly with the length of exposure time. 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

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

Note: Do not be concerned about either the DC level of this background or its shape unless it is very high, i.e., > 1000 counts with 16 bit A/D or 300 counts with a 12-bit A/D. 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 acquire and save a dark charge "background image" under conditions identical to those used to acquire the "actual" image. Subtracting the background image from the actual image will significantly reduce dark-charge effects.

Note: Offset and excess noise problems are more likely to occur if the controller and camera weren't calibrated and tested as a system at the factory.

CAUTION

If you observe a sudden change in the baseline signal you may have excessive humidity in the vacuum enclosure of the camera. Turn off the controller and arrange to have the camera vacuum pumped to restore the vacuum. *Contact the factory Technical Support for information on refreshing the vacuum.* *See page 76 for contact information.* Then resume normal operation. If problems persist call the factory.

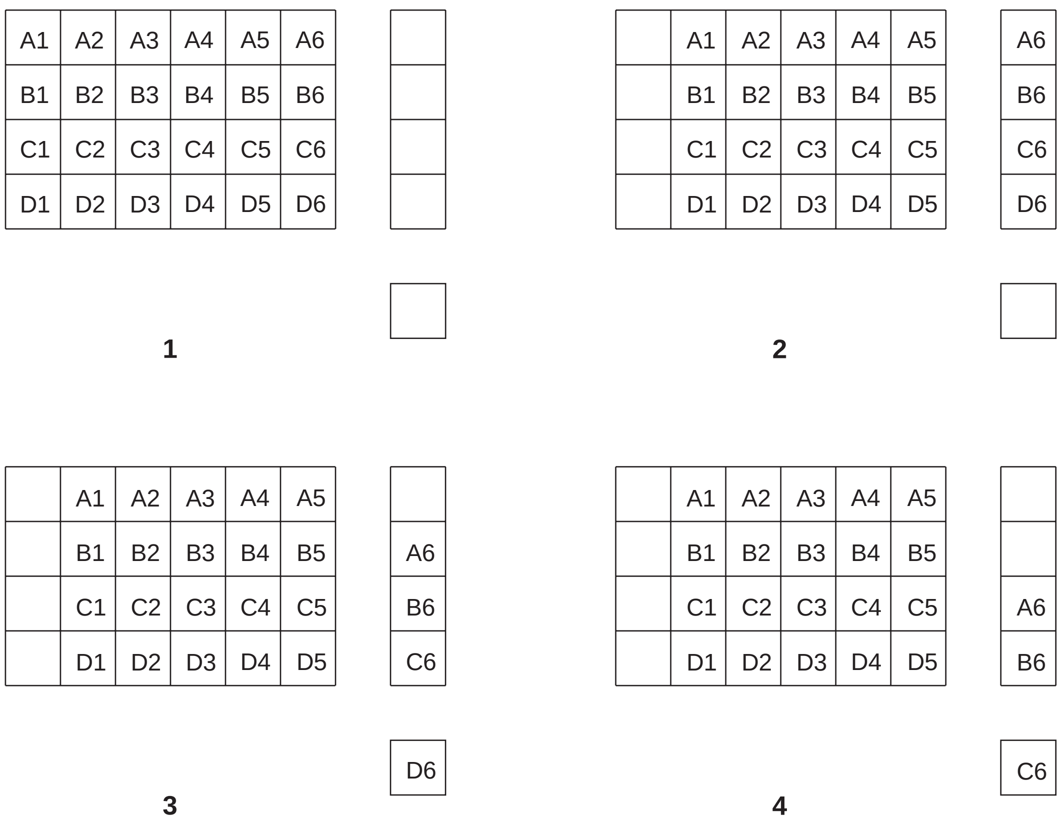
Readout of the Array

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 26 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.

Figure 26. Full frame at full resolution.



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.

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 of the CCD

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 a number of different CCD arrays are provided in Table 3 below.

Table 3. Approximate readout time of a single frame for some CCD arrays.

CCD Array	1 MHz Readout Time
EEV CCD-37 512 x 512	0.28 sec.
Kodak KAF-0400 768 x 512	0.5 sec.
Kodak KAF-1400 1317 x 1035	1.5 sec.

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.

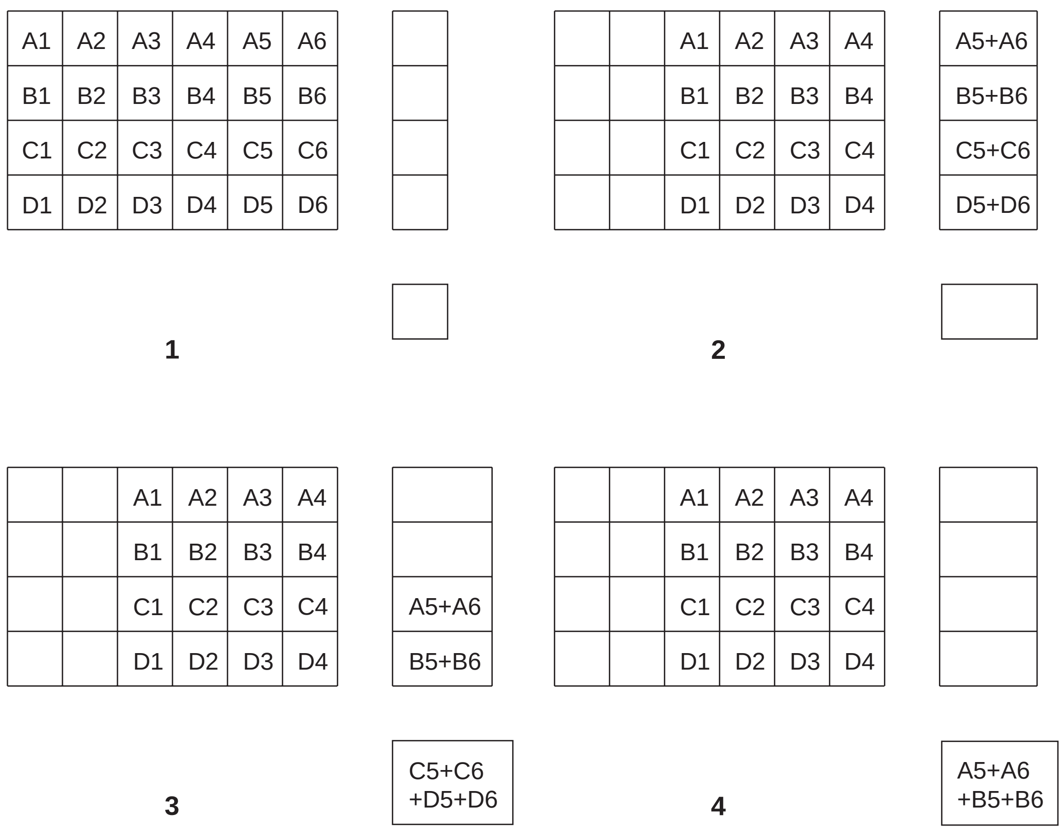
Image readout with binning

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 27 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.

Figure 27. 2 × 2 binning for images.



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:

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

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 4. Consequently, if the total charge binned together exceeds the capacity of the shift register or output node, the data will be lost.

Table 4. Well capacity for some CCD arrays.

CCD Array	Imaging Section Well Capacity	Horizontal Shift Register Well Capacity	Preamp Node Well Capacity
EEV 512 x 512	100 x 10^3 electrons	200 x 10^3 electrons	400 x 10^3 electrons
Kodak 768 x 512	85 x 10^3 electrons	170 x 10^3 electrons	340 x 10^3 electrons
Kodak 1317 x 1035	45 x 10^3 electrons	90 x 10^3 electrons	180 x 10^3 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 limited rather than photon shot-noise limited, this theoretical signal improvement cannot be fully realized. Again, background subtraction from the raw data is necessary.

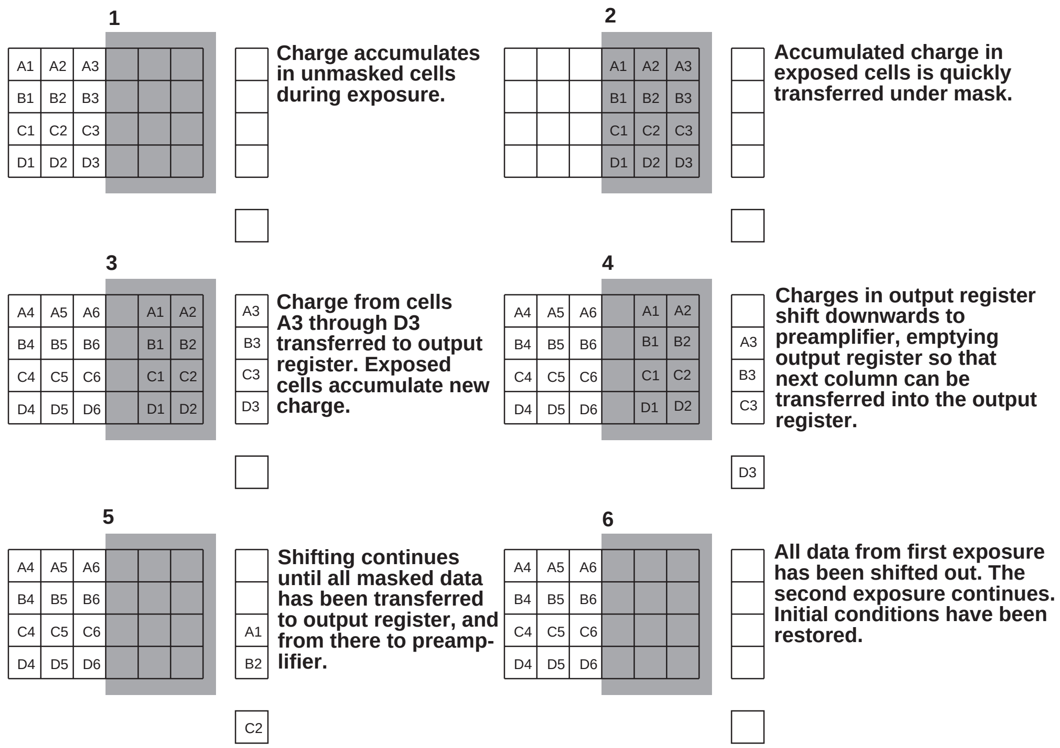
This technique is also useful in high light level experiments, where the camera is again photon shot-noise limited. Summing multiple pixels in software corresponds to collecting more photons, and results in a better S/N ratio in the measurement.

Frame transfer readout

The ST-133 5MHz fully 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 28 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 28. 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.

$$\frac{N_x t_i}{t_{exp}} \tag{4}$$

Digitization

During readout, an analog signal representing the charge of each cell (or binned group of cells) is digitized. The number of bits per cell is based on both the hardware and the settings programmed into the camera through the software.

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Appendix A
Specifications

CCD Arrays

Spectral Range

400-1080; 190-1080 nm with UV-to-visible coating on the CCD

Types

The ST-133 5MHz controller can be operated with many different Princeton Instruments cameras, each of which is available with a variety of CCD chips as specified at the time of order. Contact the factory for up-to-date information on the performance characteristics of the array installed in your particular camera.

Temperature Control

Setting Mechanism: Temperature is set by the application software.

Display: The actual temperature can be displayed at the computer by the application software.

Temperature Range: A function of camera type; see manual for your particular camera.

Time to Lock: A function of camera type; see manual for your particular camera.

Control Stability: ±0.050°C over entire temperature range.

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. Input has 10 kΩ pullup resistor. Synchronization and Trigger Modes are discussed in Chapter 6.

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 into 75 Ω.

$\overline{\text{SCAN}}$: TTL output (BNC) for monitoring camera status. TTL low when CCD is being read; otherwise high. Software allows selection of **SHUTTER MONITOR** or **$\overline{\text{SCAN}}$** signal at this connector. Default selection is **SHUTTER MONITOR**.

SHUTTER MONITOR: Alternative signal to $\overline{\text{SCAN}}$ as selected by software. Precisely brackets shutter-open time (exclusive of shutter compensation) and can be used to control an external shutter.

$\overline{\text{READY}}$: TTL output (BNC); marks start of *first* exposure. When run is initiated, remains high until completion of cleaning cycles preceding *first* exposure, then goes low and remains low for duration of run.

SERIAL COMM: Data link to computer via proprietary cable connected to this 9-pin “D” connector. Cable lengths to 165 feet (50 m) available. Fiber-optic pod available for greater distances.

A/D Converters

Converter range: 12 bits.

Readout Rate: 5 MHz.

Linearity: CCD dependent.

Readout noise: 1-1.6 counts RMS on standard controllers.

Exposure (integration time): 100 nsec to 2.3 hours (full frame or frame transfer)

Programmable Interface

TTL I/O: DB25 connector; there are eight input bits and eight output bits as described in Appendix B.

Computer Requirements

The ST-133 5MHz controller is most commonly used with an PCI-bus type Pentium computer configured as follows.

Type: Any Pentium (or better) PC having a free PCI slot.

Memory (RAM): Minimum of 32 Mbytes (64Mbytes preferred); possibly more depending on experiment design and size of CCD Array.

Operating System: Windows 95 or NT.

Interface: PCI High-Speed Serial I/O card. Can be installed in any PCI bus slot. *Computers purchased from Roper Scientific with ST-133 5MHz controllers are shipped with the card installed.*

Note: Macintosh II support may be available. Contact factory for details.

Shutter

Shutter drive capability is available as a special option for full frame CCD cameras and, if installed, operates as described.

Shutter Compensation Time: A function of the shutter type, as follows.

Shutter Type	Compensation Time
Vincent (small)	8.0 ms
Prontor 40 (large)	28.0 ms
Prontor 23 (external slit)	8.0 ms
Intensified (electronic)	6.0
NONE*	200 ns

NONE is proper shutter selection in software for an ST-133 5MHz controller operated without a shutter.

Because frame transfer CCD cameras are normally operated without a shutter, shutter drive capability is not provided with a standard ST-133 5MHz controller and the **Remote** connector opening on the panel is plugged.

Miscellaneous

Dimensions: 5.25″ (133.4mm) × 8.75″ (222.3mm) × 13.63″ (346.1mm)

Camera Weight: 3 lb max for C-mount; 3.5 lb max for F-mount,

Controller Weight: 12 lb max

Power Requirements: Nominally 100, 120, 220 or 240 V AC , 47-63 Hz, 300 watts maximum, 100 watts typical; required DC voltages are generated in the controller. Power to camera is applied via controller cable.

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

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

Appendix B
TTL In/Out Pin Assignments

Introduction

This connector provides 8 TTL lines in, 8 TTL lines out and an input control line. Figure 29 illustrates the connector and Table 6 lists the signal/pin assignments.

Princeton Instruments WinView and WinSpec software packages incorporate WinX32 Automation, a programming language that can be used to automate performing a variety of data acquisition and data processing functions, including use of the TTL IN/OUT functions. WinX32 Automation can be implemented in programs written in Vision Basic or Visual C++. See the WinX32 documentation for more detailed information.

TTL In

The user controls the 8 TTL Input lines, setting them high (+5 V; TTL 1) or low (0 V; TTL 0). When the lines are read, the combination of highs and lows read defines a decimal number which the computer can use to make a decision and initiate actions as specified in the user's program. If a TTL IN line is low, its numeric value is 0. If a TTL IN line is high, its numeric value is as follows.

TTL IN 1	1
TTL IN 2	2
TTL IN 3	4
TTL IN 4	8
TTL IN 5	16
TTL IN 6	32
TTL IN 7	64
TTL IN 8	128

This coding allows any decimal value from 0 to 255 to be defined. Thus, as many as 256 different sets of conditions can be specified, at the user's discretion, using the TTL IN lines. *Any unused lines will default to TTL high (+5 V).* For example, to define the number three, the user would simply set the lines TTL IN 1 and TTL IN 2 both high (+5 V). It would be necessary to apply TTL low to the remaining six lines because they would otherwise default to TTL high as well.

TTL IN 1	high (1)
TTL IN 2	high (2)
TTL IN 3	low (0)
TTL IN 4	low (0)
TTL IN 5	low (0)
TTL IN 6	low (0)
TTL IN 7	low (0)

Table 5 illustrates this coding for decimal values 0 through 7. Obviously this table could easily be extended to show the coding for values all the way to 255.

Table 5. Bit values with decimal equivalents; 1 = High, 0 = Low.

Decimal Equiv.	**TTL IN/OUT 8 1= dec 128**	**TTL IN/OUT 7 1=dec 64**	**TTL IN/OUT 6 1=dec 32**	**TTL IN/OUT 5 1=dec 16**	**TTL IN/OUT 4 1=dec 8**	**TTL IN/OUT 3 1=dec 4**	**TTL IN/OUT 2 1=dec 2**	**TTL IN/OUT 1 1=dec 1**
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1
2	0	0	0	0	0	0	1	0
3	0	0	0	0	0	0	1	1
4	0	0	0	0	0	1	0	0
5	0	0	0	0	0	1	0	1
6	0	0	0	0	0	1	1	0
7	0	0	0	0	0	1	1	1

Buffered vs. Latched Inputs

In controlling the TTL IN lines, users also have the choice of two input-line states, *buffered* or *latched*. In the buffered state, the line levels must remain at the intended levels until they are read. With reference to the preceding example, the high level at TTL IN 1 and TTL IN 2 would have to be maintained until the lines are read. In the latched state, the applied levels continue to be available until read, even if they should change at the TTL IN/OUT connector.

This control is accomplished using the EN/CLK TTL input (pin 6). If EN/CLK is open or high, *buffered* operation is established and the levels reported to the macro will be those in effect when the READ is made. With reference to our example, if pin 6 were left unconnected or a TTL high applied, TTL IN 1 and TTL IN 2 would have to be held high until read. If, on the other hand, EN/CLK were made to go low while TTL IN 1 and TTL IN 2 were high, those values would be *latched* for *as long as EN/CLK remained low*. The levels actually present at TTL IN 1 and TTL IN 2 could then change without changing the value that would be read by software.

TTL Out

The state of the TTL OUT lines is set from WinView/32. Typically, a program monitoring the experiment sets one or more of the TTL Outputs. Apparatus external to the ST-133 5MHz interrogates the lines and, on detecting the specified logic levels, takes the action appropriate to the detected condition. The coding is the same as for the input lines. There are eight output lines, each of which can be set low (0) or high (1). The combination of states defines a decimal number as previously described for the TTL IN lines.

Table 6. TTL In/Out connector pinout.

Pin #	Assignment	Pin #	Assignment
1	IN 1	14	IN 2
2	IN 3	15	IN 4
3	IN 5	16	IN 6
4	IN 7	17	IN 8
5	GND	18	GND
6	EN/CLK	19	Reserved
7	(future use)	20	GND
8	GND	21	OUT 2
9	OUT 1	22	OUT 4
10	OUT 3	23	OUT 6
11	OUT 5	24	OUT 8
12	OUT 7	25	GND
13	Reserved		

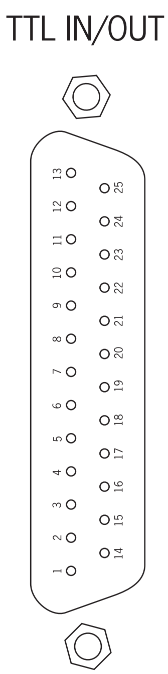

Figure 29. TTL IN/OUT connector.

TTL Diagnostics Screen

Note that WinView/32 provides a TTL Diagnostics screen (located in WinView/32 under *Hardware Setup - Diagnostics)* that can be used to test and analyze the TTL In/Out lines.

Hardware Interface

A cable will be needed to connect the TTL In/Out connector to the experiment. The design will vary widely according to each user's needs, but a standard 25-pin female type D-subminiature connector will be needed to mate with the TTL In/Out connector at the ST-133 5MHz controller. The hardware at the other end of the cable will depend entirely on the user's requirements. If the individual connections are made using coaxial cable for maximum noise immunity (recommended), the center conductor of the coax should connect to the proper signal pin and the cable shield should connect to the nearest available ground (grounds are conveniently provided at pins 5, 8, 18 and 20). Connector hardware and cables of many different types are widely available and can often be obtained locally. A list of possibly useful items follows. Note that, although the items listed may be appropriate in many situations, they might not meet your specific needs.

- 25-pin female type D-subminiature solder type connector (Radio Shack part no 276-1548B).
- RG/58U coaxial cable.
- Shielded Metalized hood (Radio Shack part no 276-1536A).
- BNC connector(s) type UG-88 Male BNC connector (Radio Shack part no 278-103).

Example

Suppose you needed to build a cable to monitor the line TTL OUT 1. One approach would be to build a cable assembly as described in the following paragraphs. This procedure could easily be adapted to other situations.

- Begin with a 25-pin female type D-subminiature solder type connector (Radio Shack part no 276-1548B). This connector has 25 solder points open on the back.
- Referring to Table 6, note that pin 8 = GND and pin 9 = TTL OUT 1.
- Using coaxial cable type RG/58U (6 feet length), strip out the end and solder the outer sheath to pin 8 (GND) and the inner line to pin 9 (TTL OUT 1). Then apply shielding to the lines to insulate them.
- Mount the connector in a Shielded Metalized hood (Radio Shack part no 276-1536A).
- Build up the cable (you can use electrical tape) to where the strain relief clamp holds.
- Connect a BNC connector (UG-88 Male BNC connector) to the free end of the cable following the instructions supplied by Radio Shack on the box (Radio Shack part no 278-103).
- To use this cable, connect the DB-25 to the TTL IN/OUT connector on the back of the ST-133 5MHz controller.
- To check the cable, start WinView/32 and open the TTL Diagnostics screen (located in WinView/32 under *Hardware Setup - Diagnostics*). Click the **Write** radio button. Then click the **Output Line 1** box. Next click the **OK** button to actually set TTL OUT 1 high. Once you set the voltage, it stays until you send a new command.

- Measure the voltage at the BNC connector with a standard voltmeter (red on the central pin, black on the surrounding shielding). Before clicking **OK** at the TTL Diagnostics screen you should read 0 V. After clicking **OK** you should read +5 V.

Note that adding a second length of coaxial cable and another BNC connector would be straightforward. However, as you increase the number of lines to be monitored, it becomes more convenient to consider using a multiple conductor shielded cable rather than individual coaxial cables.

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Appendix C
Cleaning Instructions

Controller and Camera

Although there is no periodic maintenance that *must* be performed on the ST-133 5MHz Controller or on the Camera, users are advised to clean these components from time to time by wiping them down with a clean damp cloth. This operation should only be done on the external surfaces and with all covers secured. In dampening the cloth, use clean water only. No soap, solvents or abrasives should be used. Not only are they not required, but they could damage the finish of the surfaces on which they are used.

Optical Surfaces

Optical surfaces may need to be cleaned due to the accumulation of atmospheric dust. We advise that the *drag-wipe* technique be used. This involves dragging a clean cellulose lens tissue dampened with clean anhydrous methanol over the optical surface to be cleaned. Do not allow any other material to touch the optical surfaces.

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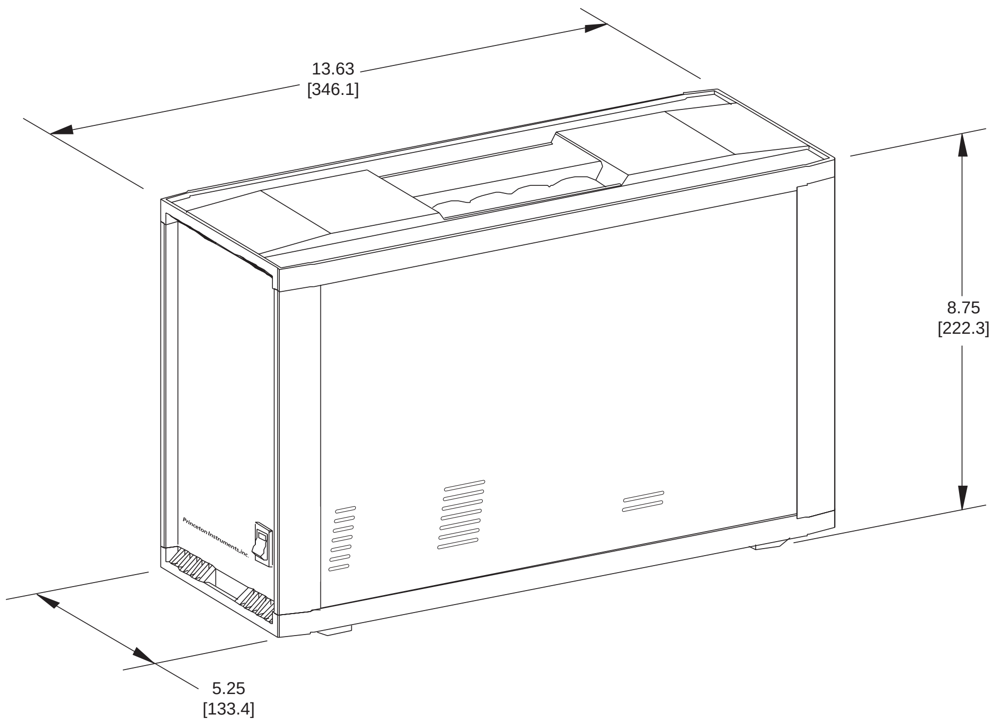
Appendix D

Outline Drawing of ST-133 5MHz Controller

Figure 30. ST-133 5MHz Controller dimensions.



Dimensions are in inches and mm.

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Appendix E
Plug-In Modules

Introduction

The ST-133 5MHz Controller has three plug-in slots. Two of these slots are used for plug-in modules. The third, covered with a blank panel, is reserved for future controller enhancements. The Analog/Control module plugs into the left-most slot as seen from the rear, the Interface Control module plugs into the center slot, and the blank panel is installed over the right-hand slot. Although the modules can function electrically in any slot, for optimum controller performance each module must be located as indicated. If a module is ever removed for any reason, internal settings should ***not*** be disturbed. Changing a setting could radically alter the controller's performance. Restoring normal operation again without proper equipment and guidance would be very difficult, and it might be necessary to return the unit to the factory for recalibration.

WARNING

Modules should ***never*** be removed or installed when the controller is under power. If a module is removed or installed when the controller is powered, permanent equipment damage could occur.

Removing/Installing a Module

To remove a module, rotate the two locking screws (one at the top of the module and one at the bottom) counterclockwise until they release from the chassis. Then grasp the module and pull it straight out.

Installing a module is a bit more complex because you first have to be sure the locking screws are aligned correctly. The following procedure is suggested.

- Rotate the two locking screws counterclockwise until the threads on the screws engage those of the module panel. *See Figure 31.* By doing this, the screws will be perfectly perpendicular to the module panel and will align perfectly when the module is inserted.
- Insert the module so that the top and bottom edges of the board are riding in the proper guides.
- Gently but firmly push the module in until the 64-pin DIN connector at the back of the module mates with the corresponding connector on the backplane, leaving the module panel resting against the controller back panel.
- Rotate the two locking screws clockwise. As the screws are rotated, they will first disengage from the module panel threads, and then begin to engage those of the bracket behind the controller panel.

WARNING

Tighten the screws to where they are just snug. Do ***not*** tighten them any further because you could easily bend the mating bracket.

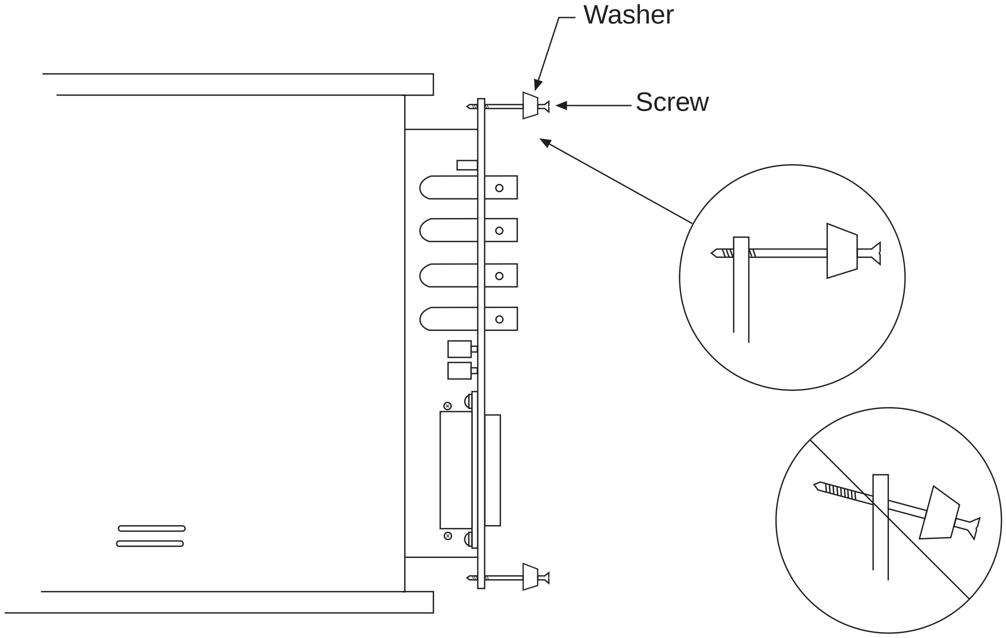

Figure 31. Module Installation.

Warranty & Service

Limited Warranty: Roper Scientific Analytical Instrumentation

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

Basic Limited One (1) Year Warranty

Roper Scientific 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, Roper Scientific 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 Roper Scientific 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 Roper Scientific authorized representative/distributor for repair information and assistance, or visit our technical support page at www.roperscientific.com.

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

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

Shutter Limited One Year Warranty

Roper Scientific warrants for a period of up to one (1) year after shipment the standard, factory-installed camera shutter of all our products that incorporate an integrated shutter. This limited warranty applies to the standard shutter installed in the camera system at the time of manufacture. *Non-standard shutters, special product request (SPR) shutters, and third-party shutter drive equipment carry NO WARRANTIES EXPRESSED OR IMPLIED.* Roper Scientific will supply, at no cost to the customer, up to one (1) replacement shutter during the warranty period. Roper Scientific will, at Roper Scientific's option, either ship a ready-to-install shutter to the customer site for installation by the customer according to the instructions in the product User Manual or arrange with the customer to return the camera system (or portion of the camera system) to the factory (or factory-authorized service center) for shutter replacement by us or a Roper Scientific-authorized agent. Responsibility for shipping charges is as described above under our Limited One (1) Year Warranty.

VersArray (XP) Vacuum Chamber Limited Lifetime Warranty

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

Sealed Chamber Integrity Limited 24 Month Warranty

Roper Scientific 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

Roper Scientific 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.

Image Intensifier Detector Limited One Year Warranty

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

X-Ray Detector Limited One Year Warranty

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

Software Limited Warranty

Roper Scientific warrants all of our manufactured software discs to be free from substantial defects in materials and / or workmanship under normal use for a period of one (1) year from shipment. Roper Scientific does not warrant that the function of the software will meet your requirements or that operation will be uninterrupted or error free. You assume responsibility for selecting the software to achieve your intended results and for the use and results obtained from the software. In addition, during the one (1) year limited warranty. The original purchaser is entitled to receive free version upgrades. Version upgrades supplied free of charge will be in the form of a download from the Internet. Those customers who do not have access to the Internet may obtain the version upgrades on a CD-ROM from our factory for an incidental shipping and handling charge. *See Item 12 in the following section of this warranty ("Your Responsibility") for more information.*

Owner's Manual and Troubleshooting

You should read the owner’s manual thoroughly before operating this product. In the unlikely event that you should encounter difficulty operating this product, the owner’s manual should be consulted before contacting the Roper Scientific 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 Roper Scientific technical support staff or our authorized service representative. *See Item 12 in the following section of this warranty ("Your Responsibility") for more information.*

Your Responsibility

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

1. You must retain your bill of sale (invoice) and present it upon request for service and repairs or provide other proof of purchase satisfactory to Roper Scientific.
2. You must notify the Roper Scientific 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 Roper Scientific factory or, at our option, an authorized service center.
4. Before products or parts can be returned for service you must contact the Roper Scientific 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 Roper Scientific factory or one of our authorized manufacturer's representatives or distributors.
6. Unless specified in the original purchase agreement, Roper Scientific 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 Roper Scientific.
8. After the warranty period has expired, you may contact the Roper Scientific factory or a Roper Scientific-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 Roper Scientific’s liability exceed the cost of the repair or replacement of the defective product or part.
11. This limited warranty gives you specific legal rights and you may also have other rights that may vary from state to state and from country to country. Some states and countries do not allow limitations on how long an implied warranty lasts, when an action may be brought, or the exclusion or limitation of incidental or consequential damages, so the above provisions may not apply to you.
12. When contacting us for technical support or service assistance, please refer to the Roper Scientific factory of purchase, contact your authorized Roper Scientific representative or reseller, or visit our technical support page at www.roperscientific.com.

Contact Information

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

Roper Scientific
3660 Quakerbridge Road
Trenton, NJ 08619 (USA)

Tel: 609-587-9797
Fax: 609-587-1970

Technical Support E-mail: techsupport@roperscientific.com

For technical support and service outside the United States, see our web page at www.roperscientific.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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