SPECTRUM ONE

CCD Detection System

With CCD2000 and CCD3000 Controllers
Including CCDLOAD.EXE and
CCD3000.EXE Drivers plus Windows DLL

Part Number 80119 Rev H
Includes former 80120

Revised August 11, 2004

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ABOUT THE MANUALS

You may have more than one manual, depending on your system configuration. To find the manual that has the information you need, these guidelines may help.

- Each manual generally covers a product and the features and accessories peculiar to and/or contained within that product.
- Accessories that can be applied to other products are normally covered by separate documentation.
- Software that is exclusively used with one instrument or system is covered in the manual for that product.
- Software that can be used with a number of other products is covered in its own manual.
- If you are reading about a product that interacts with other products, you will be referred to other documentation as necessary.

TABLE OF CONTENTS:

OVERVIEW:

The Spectrum One CCD detector systems are a family of products shared by the SPEX and Jobin-Yvon spectrometer product lines of Instruments SA.

The Spectrum One series detectors are cooled Charge Coupled Devices (CCD's) which provide two-dimensional photodetection for spectrometric applications. These detectors can be interfaced to the exit port of most SPEX and J-Y spectrographs, including those in fluorometers and Raman instruments.

The glossary section of this manual starts on page 43. It contains definitions of terms and information about essential topics relating to CCD detection of spectra. Reading the glossary is recommended.

The Spectrum One CCD system is well suited to applications such as:

- Low or very low signal levels such as Raman, fluorescence, and absorption spectroscopy.
- Recording the spectra from multiple sources or locations that are imaged along the height of the spectrograph entrance slit.
- Near IR measurements to 1100 nm.

SYSTEM COMPONENTS:

The Spectrum One CCD detection system consists of a detector head, a detector interface unit, and software. Additionally if the CCD2000 controller is used, a communications card which plugs into an IBM compatible PC with an available AT-style slot is required to run the system. If using the CCD3000 controller, a National Instruments IEEE-488 GPIB card is required to run the system.

Caution: Electrostatic discharge may damage components of the Spectrum One system if proper precautions are not taken. Refer to page 16 for instructions.

CCD Detector Heads:

The Spectrum One CCD array head is available with three cooling options. When the lowest noise and dark level is required, liquid nitrogen (LN_2) provides cryogenic cooling to reduce temperature and therefore, dark current, to the lowest level possible.

Three types of thermoelectrically cooled heads are offered: a water cooled and two air cooled. The water cooled head requires circulating or flowing water rather than LN_2. It provides operating temperature lower than the air cooled, though not nearly as low as the LN_2 cooled heads. The air cooled heads operate at higher temperature, but require no water or LN_2. For all heads, a resistive heater mounted in the detector allows software controlled temperature stabilization.

LN_2 Cooled CCD Heads:

LN_2 cooled Spectrum One heads are mounted in one of three types of liquid nitrogen dewar assemblies.

The 1 liter capacity dewar shown in Figure 1 is designed to maintain the CCD sensor cooled for at least 24 hours before refilling with liquid nitrogen.

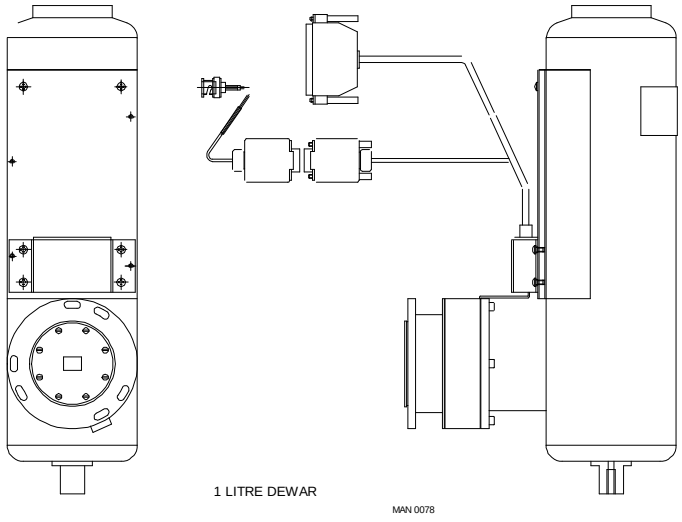


Figure 1: Spectrum One LN_2 cooled head 1 liter dewar
MAN0078

The 2.8 liter dewars shown in figures 2 & 3 require refilling about every 72 hours in a room temperature environment.

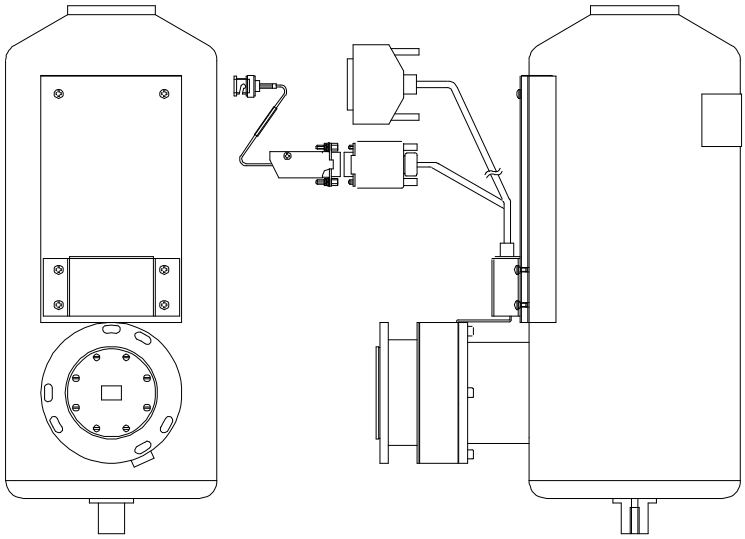


Figure 2: Spectrum One 2.8 liter Side-looking LN_2 dewar
MAN0079

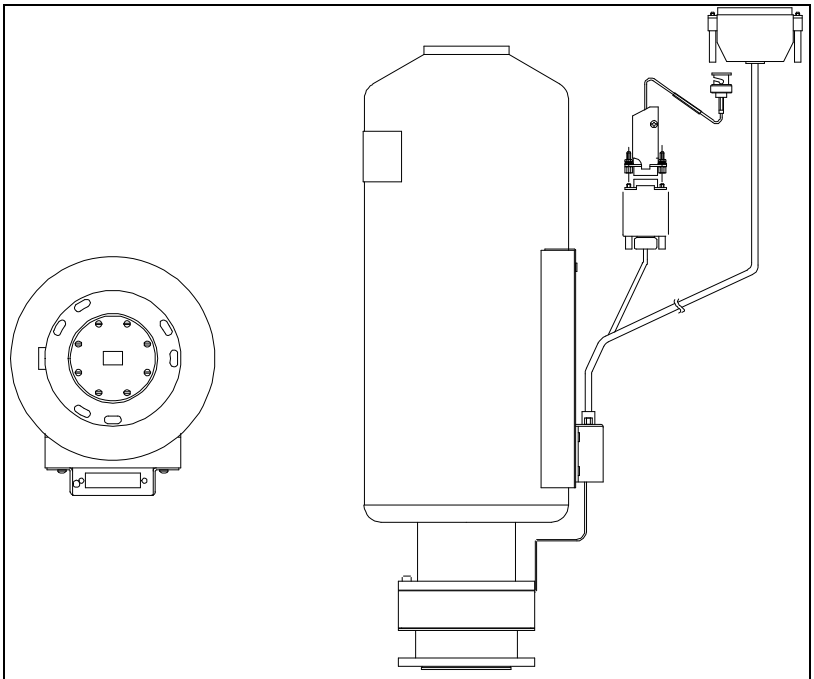


Figure 3: Spectrum One 2.8 liter down-looking LN_2 dewar
MAN0050

Thermoelectrically Cooled CCD Heads:

Either liquid or air heat exchangers are provided for thermoelectrically cooled CCD detector heads. All types employ stage Peltier effect cooling devices inside evacuated or purged chambers. Several chip options are available in each type. These TE cooled heads can run continuously at their set operating temperature without refilling. For liquid cooled heads, a filter to remove particulates and other residue from the coolant is required to assure consistent heat exchanger performance. If a recirculating bath is used, it must have the capacity to dissipate more than 100 watts.

The air cooled heads require only freely circulating ambient room temperature air to maintain cooling. A nominal air temperature of 22°C (72°F) is recommended. If the ambient air temperature at the head reaches 40°C (104°F), the chip temperature will certainly be affected. The total dissipation from the head will be about 100 watts. If the head must be mounted inside an enclosure, provide for forced ventilation to assure that the temperature in the enclosure is maintained at or below 35°C (95°F) for best results. If these conditions are not met, the operating temperature will be affected, and performance will be degraded.

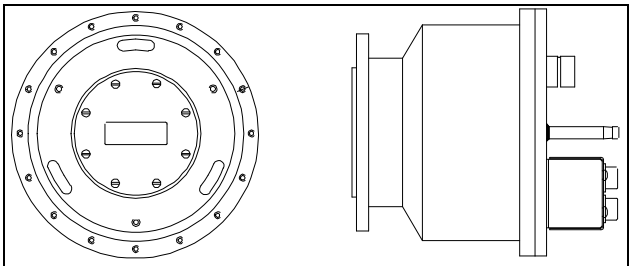


Figure 4: Spectrum One TE water cooled head
MAN0087

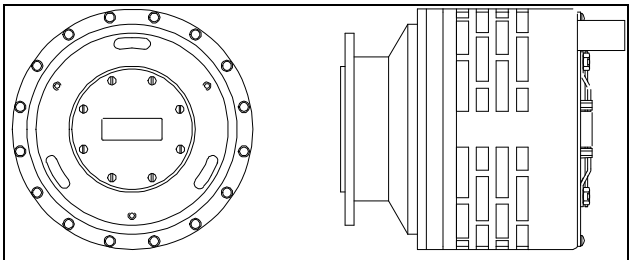


Figure 5: Spectrum One ATE air cooled head
MAN0089

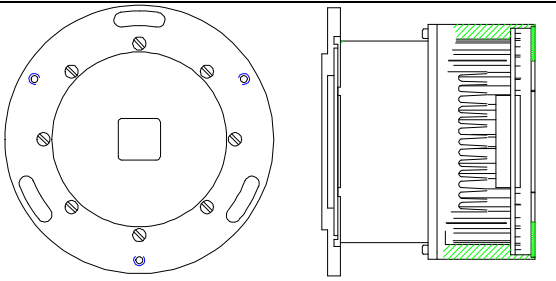


Figure 6: Spectrum One MTE air cooled head
MAN 0110

With unrestricted airflow, the heat sink runs nominally 13°C above ambient. If, by airflow restriction or excessive ambient temperature, the heat sink ever exceeds 60°C, a sensor will signal the Peltier cooler power supply to shut down. In this way, damage to the head is prevented.

Detector Head Evacuation:

All Spectrum One detector heads except the MTE Mini head have a high vacuum chamber that holds the CCD chip. In the MTE head, the chamber is dried and filled with dry nitrogen at the factory. This chamber, along with other insulating measures, isolates the chip from the ambient temperature. The heads are evacuated or purged at the factory. They are designed to maintain insulating properties for a minimum of one year between pumping or purging cycles. A leak will result in a decrease in the insulating capability of the head. Thermoelectrically cooled heads will be unable to achieve their rated operating temperatures. LN_2 heads will rapidly consume the liquid nitrogen, and frost may form on the exterior of the dewar. In either case, condensation may form on the array during cool down cycles, degrading optical performance and fostering corrosion. You may notice spreading of light to nearby pixels. Spectral features may become blurred.

If the head cannot maintain operating temperature, contact ISA to arrange for re-pumping the vacuum or re-purging instructions. See page 14 for operating temperature specifications. Any attempts to evacuate the Spectrum One head at user locations are not recommended. Some types of vacuum pumps can backstream oil, causing *irreparable damage* to the CCD electronics. In the event of loss of vacuum, please contact the ISA Service Department according to the directions given on page 41.

CCD 2000 Detector Controller:

The CCD2000 Detector Controller Unit shown in controls the CCD head based on commands from the computer. This unit supplies power, clocking signals, and biases to the CCD sensor array. If the head is TE cooled, it provides power to the Peltier cooler. The Controller unit also amplifies and digitizes the signal as it is collected from the CCD.

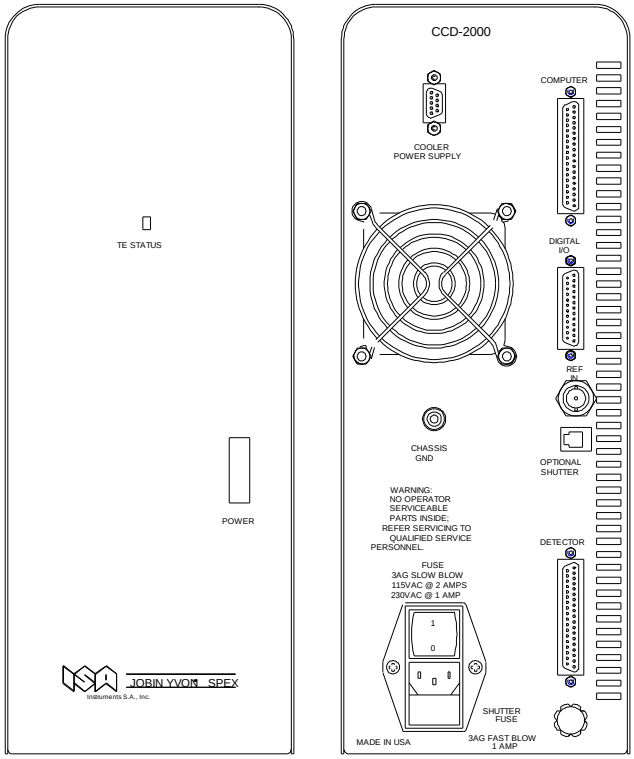


Figure 7: CCD2000 Detector Controller

MAN0107

CCD 3000 Detector Controller:

The CCD3000 Detector Controller Unit shown in Figure 8 controls the CCD head based on commands from the computer. This unit supplies power, clocking signals, and biases to the CCD sensor array. The Controller unit also amplifies and digitizes the signal as it is collected from the CCD.

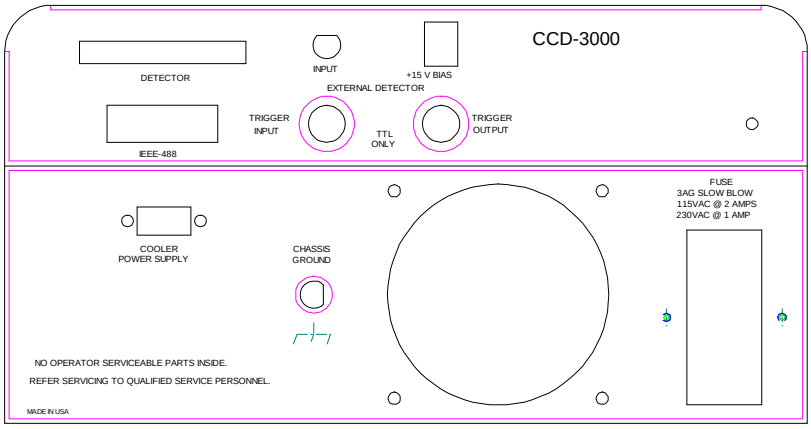


Figure 8: CCD 3000 Detector Controller

Triggering with CCD3000 Controller

The CCD3000 has two external trigger ports: TRIGGER INPUT and TRIGGER OUTPUT. If using SpectraMax for Windows software with triggers enabled, when the controller is ready to acquire, the TRIGGER OUTPUT line is moved high and the controller waits for a positive pulse from the TRIGGER INPUT to start the acquisition. When an input pulse is received, the output line is moved low until the controller is ready for the next acquisition. The triggers can also be controlled via a user programmed interface (See appendix sections for more information).

PC Communications Card

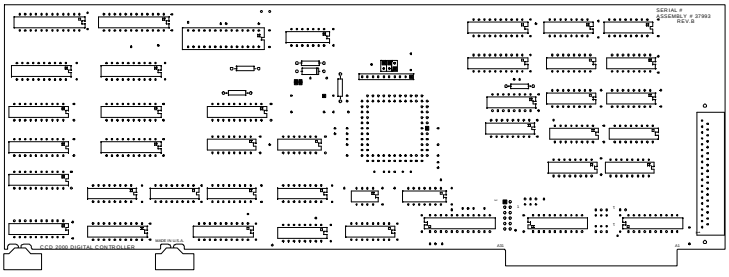


Figure 9: PC Communications card

CCD 2000:

To facilitate the high speed data transfer needed to and from the CCD detector, a Reduced Instruction Set Computer (RISC) is employed on the communications card (see figures 9). The RISC card must be mounted in the IBM compatible PC to allow the computer to communicate with and operate the Detector Interface Unit.

CCD 3000:

This controller is designed to transfer data via IEEE-488 communication. If using ISA software, the user must supply a National Instruments compatible card. The following cards are approved National Instruments PC interface boards:

- AT-GPIB/TNT and AT-GPIB/TNT(PNP)
- GPIB-PCII/PCIIA 488.2 Interface board: The driver supplied by National should be version 1.2 or newer, and their BASIC support disk should be version 2.0 or newer.
- Older GPIB-PCIIA boards require National's revision C13 or newer software.
- AT-GPIB 488 boards require National's revision E7 or newer software.
- AT-GPIB 488.2 board: Must be version 2.1.1 software, and their BASIC support disk version 2.2 or newer.
- GPIB-PCIII board: this model must be replaced with one of the above.

There are other boards by National and other suppliers for IBM compatible computers. Many of these boards can function in SIMILAR fashion. As we **cannot support** or **guarantee** reliable communications with other boards and software, we **strongly** recommend that you use the National Instruments products described above.

Software:

A variety of software options are available from Instruments SA to operate the Spectrum One CCD detector system. Please refer to the documentation provided with the software shipped with the system.

Instruments SA is committed to continuous development and improvement of software. To the extent possible, new software options are developed with backward compatibility. In this way, normally an existing system can be upgraded as new software is developed.

It is advisable to keep in contact with Instruments SA to be sure that updates and new software options that can enhance the system's functionality are considered as they become available.

OPERATING PRINCIPLES:

CCD detector arrays are essentially large area silicon photodiodes constructed such that the area is divided into a two dimensional matrix of pixels.

When illuminated by opening the shutter, each pixel integrates a charge arising from the photoelectric effect. The charges of adjacent pixels are kept separated by a grid of electrodes that confine the charges by electrostatic force.

At the end of the signal integration time the shutter is closed. Then the electrode grid voltages are manipulated by control signals from the Detector Interface Unit. This will sequentially shuttle the pixel charges row by row or column by column to the edge of the chip into a read out register. Based on the controlling software's settings, the Detector Interface Unit can cause the readout to be formatted as either individual pixel datapoints or as areas of several pixels binned into superpixels.

The signal from the CCD is processed, amplified and converted to digital datapoints by electronics in the Detector Interface Unit.

The data is passed from the Detector Interface Unit to the memory of the computer. This allows the software running in the host PC to access it rapidly for further processing and display.

The readout rate of a slow scan scientific grade CCD is about 20 kHz. The CCD's used in television cameras, where S/N is less critical, scan at about 60 MHz.

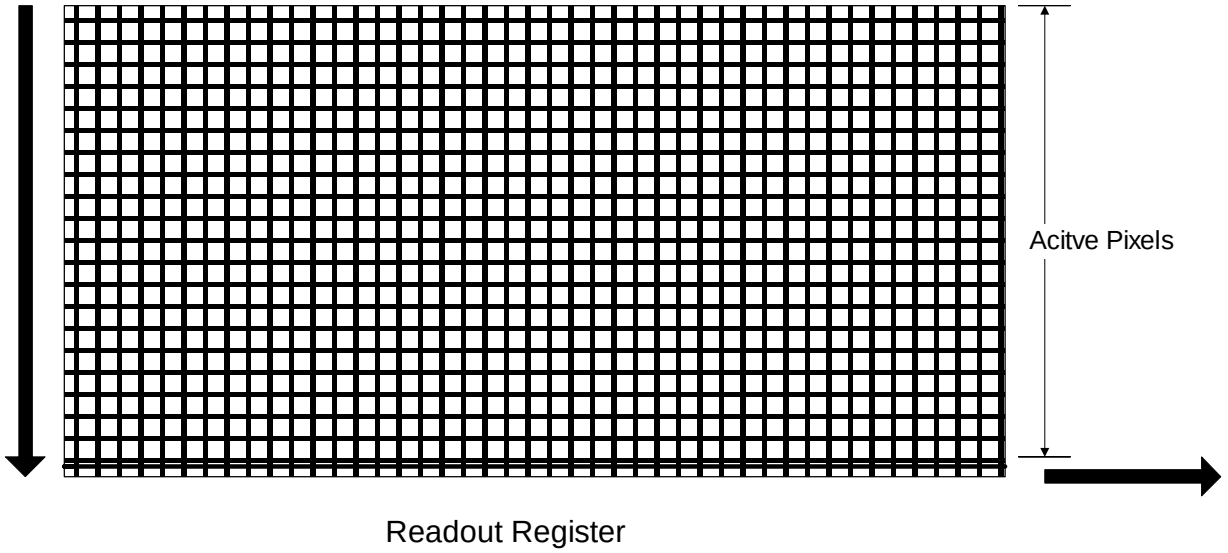
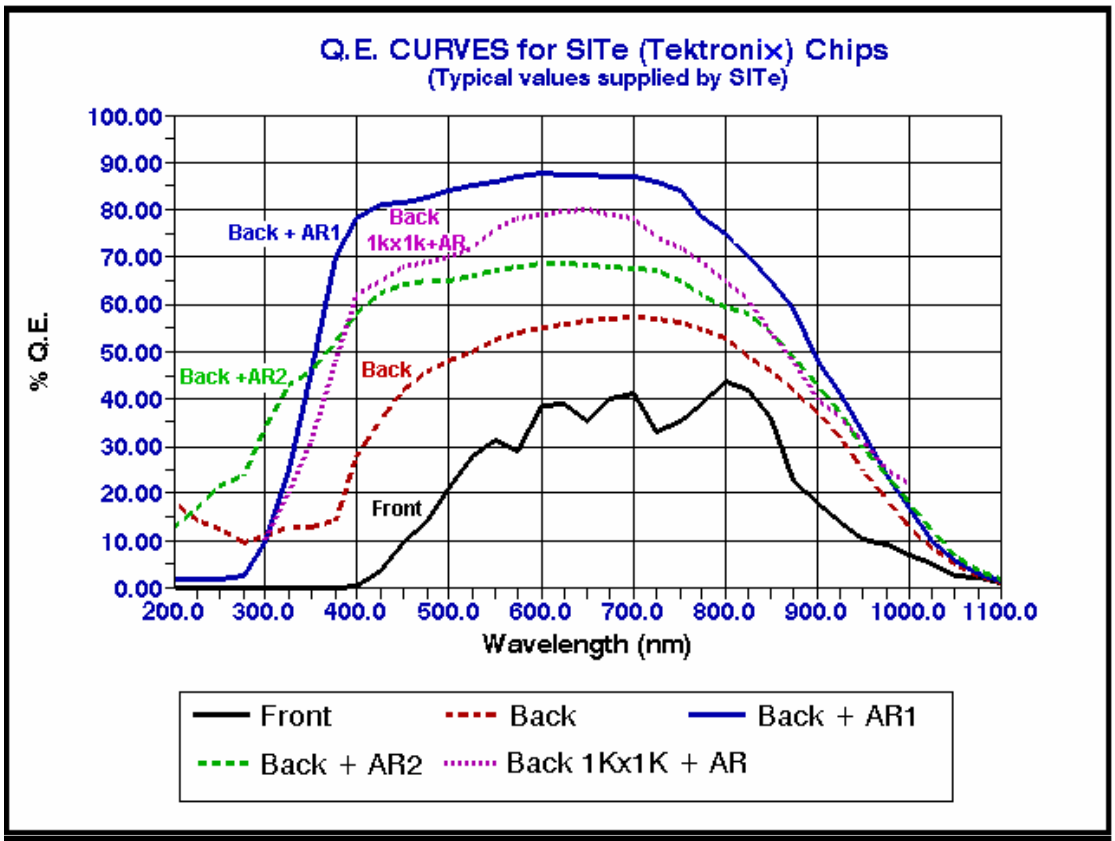


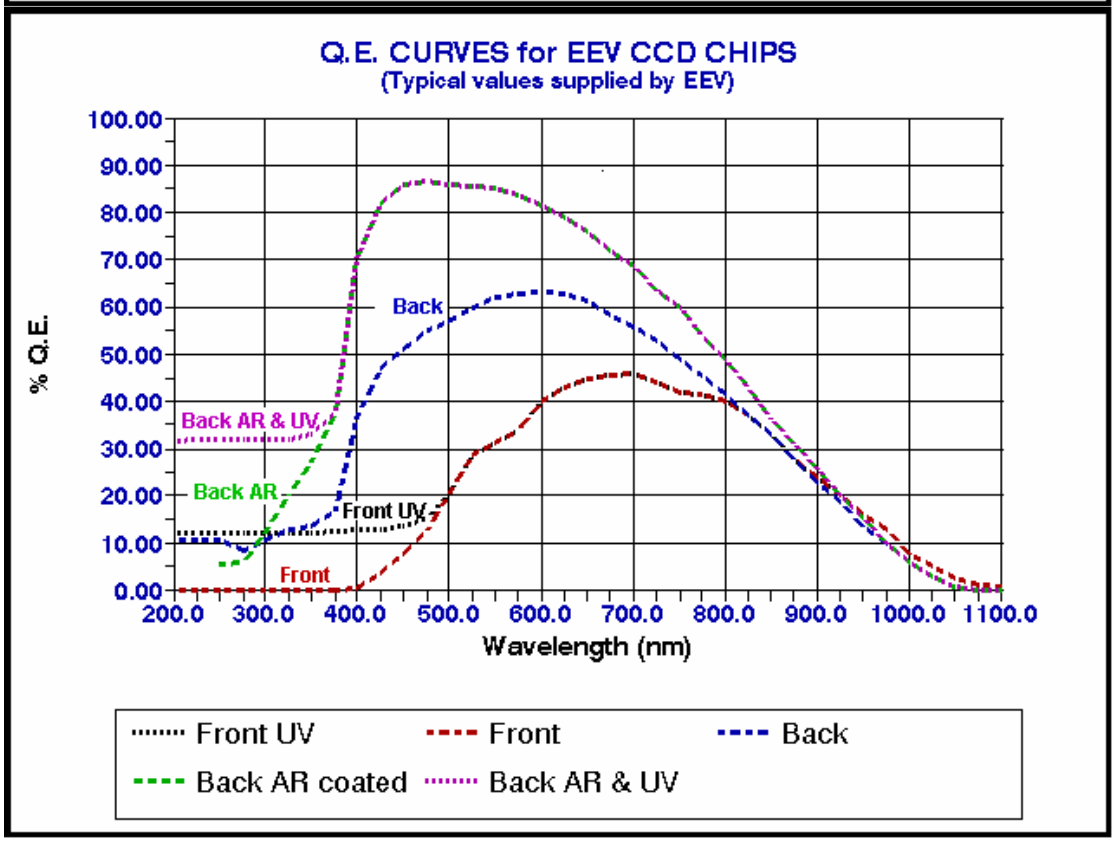
Figure 10: CCD Readout Registers

SPECIFICATIONS:

ADC Precision:	16-bit	
Dark Current:	LN_2 Cooled Head:	< 1 to 3 e-/pixel/hour (chip dependent)
	H_20 Cooled Head:	< 50 electrons/pixel/hour
	Air Cooled Head:	< 250 electrons/pixel/hour
	Mini Air Cooled Head:	< 2.5 electrons/pixel/second
Dynamic Range:	65535 counts max.	
Electrons/Count:	Variable, from 1 to 16 e-/count	
Exposure Time:	>10 milliseconds to hours	
Typical Operating Temperature:	LN_2 Cooled Head:	-140^o C typical, (1024 x 256 pixels, larger -70 to -140^o C range chips slightly higher)
H_20 Cooled Head:	-60^oC (water 12^o C)	
Air Cooled Head:	-55^oC (air 22^o C)	
Mini Air Cooled Head:	Not specified	
Quantum Efficiency:	Standard chips:	Up to 50% at 750 nm.
Backthinned chips:	Up to 85% at 550 nm.	
Spectral Response:	Standard chips:	400 to 1050 nm.
With UV coating:	200 to 1050 nm	
Readout Noise:	LN_2 Cooled Head:	4 to 10 electrons RMS per pixel or binned datapoint, depending on chip selected
H_20 Cooled Head:	10 to 18 electrons RMS per pixel or binned datapoint, depending on chip selected	
Air Cooled Head:	10 to 20 electrons RMS per pixel or binned datapoint	
Mini Air Cooled Head:	10 to 20 electrons RMS per pixel or binned datapoint	

Specifications are subject to change without notice.


Q.E. CURVES for SITe (Tektronix) Chips
(Typical values supplied by SITe)
% Q.E.
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0
1100.0
Wavelength (nm)
Back + AR1
Back 1kx1k+AR
Back +AR2
Back
Front
Front
Back
Back + AR1
Back + AR2
Back 1Kx1K + AR


Q.E. CURVES for EEV CCD CHIPS
(Typical values supplied by EEV)
% Q.E.
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0
1100.0
Wavelength (nm)
Back
Back AR & UV
Back AR
Front UV
Front
Front UV
Front
Back
Back AR coated
Back AR & UV

HARDWARE INSTALLATION:

Warning:

The CCD head, the Detector Interface Unit, the RISC board and the computer are very sensitive to electrostatic discharge (ESD). ESD precautions should be followed. The installer should stand on a conductive mat and wear a grounded wrist strap during installation. The computer must be turned off, but its power cord should be connected to a grounded outlet to take advantage of the outlet ground.

Always turn the power off to all components before connecting or disconnecting any cables.

Before inserting a connector, touch the connector shell to the component case to discharge any accumulated static charge.

Communications Card (for the CCD 2000 only):

Mount the Spectrum One communications card in the computer to allow connection of the Detector Interface Unit to the computer.

To install the communications card:

1) Shut off the computer and remove the chassis cover.

2) Choose a slot (AT-style) as far from the video and disk cards as is practical (These cards have been know to artificially increase the noise level.) Remove the rear panel slot cover, retaining the screw.

3) Insert the edge connector of the communications card shown into the chosen slot, making sure of good contact. Fasten the back plate with the screw removed from the slot cover and replace the chassis cover of the computer.

Detector Head Mounting:

The Spectrum One can be retrofitted to an existing Spex or J-Y spectrometer that can be equipped with a spectrograph exit port. Instructions for adding the appropriate spectrograph ports follow. If the spectrograph port is already installed, note the mask on the face of the detector before mounting. This mask is offset to one side to accommodate the tilt of the focal plane without vignetting.

For Raman Systems:

User installation of the CCD on the S30900, U1000, and T64000 is not recommended without first consulting with ISA's Raman Service Department (see service policy section on page 41).

Thermoelectrically cooled Spectrum One heads can be mounted on any ISA Raman system. For the S3000, use the model 640.20.10.10 adapter which also can mount a side-looking LN2 dewar as well.

The U1000 requires the model 505.85.911 adapter. Either down-looking dewars or TE heads can be mounted on the 505.85.911.

The T64000 has a built-in port for the down-looking dewars or TE heads, a side looking dewar or additional TE head mounting can be added by mounting the optional T64.POR adapter.

For the 270M:

Use the 270MCA adapter. Refer to the 270M manual for instructions.

For HR320, THR640, THR1000:

The model 303.50.713 XYZ Spectrograph port (see figure 14) is the adapter used for the HR320, THR640, and THR1000. This will adapt the side-looking CCD dewar or TE cooled CCD head to the spectrometer. Remove the slit assembly or cover from the exit port by unscrewing the three mounting bolts. Bolt the Detector Mounting Adapter onto the port. The adapter consists of two sections, one of which fits into the other. Bolt the mounting fixture to the outer surface of the port plate (wall) using the three included screws. The HR320 uses M5x10 flathead screws while the THR640 and THR1000 use M4x12 flathead screws. Orient the mounting fixture such that the notch is to the left. Then mount the tilting/focusing adapter with the groove in the flange and the swivel washer set at the top. Snug the thumb-nuts. They will be tightened later when finished with the tilting and focusing adjustments. Bolt the Spectrum One head to the detector mounting flange. Snug the three bolts. These will be tightened later after the rotation adjustment is completed.

For the 1681C and 340E

Use adapter 33519 (figure 11) and bolt the mounting adapter to the outside of the spectrometer wall. Bolt the detector mounting flange to the detector. Then insert the detector mounting flange into the mounting adapter. Snug the radial set screws that hold the detector flange inside the mounting fixture. These set screws will be tightened later, after focusing and rotating.

For the 500M, 1000M, 1250M

Use the M-series adapter 1497 (figure 12) and bolt the mounting adapter to the outside of the spectrometer wall. Bolt the detector mounting flange to the detector. Then insert the detector mounting flange into the mounting adapter. Snug the radial set screws that hold the detector flange inside the mounting fixture. These set screws will be tightened later, after focusing and rotating.

For the 1877

Use adapter 32887 (figure 13) and bolt the mounting adapter to the outside of the spectrometer wall. Bolt the detector mounting flange to the detector. Then insert the detector mounting flange into the mounting adapter. Snug the radial set screws that hold the detector flange inside the mounting fixture. These set screws will be tightened later, after focusing and rotating.

For the 1269

Use spectrometer adapter 35420 (figure 15) and bolt the mounting adapter to the outside of the spectrometer wall. Bolt the detector mounting flange to the detector. Then insert the detector mounting flange into the mounting adapter. Snug the radial set screws that hold the detector flange inside the mounting fixture. These set screws will be tightened later, after focusing and rotating.

For the 750M, 1403 or 1404

Install the 1497 adapter as described above, but bolt the mounting adapter section to the inside surface of the spectrometer wall. See the left view in figure 12.

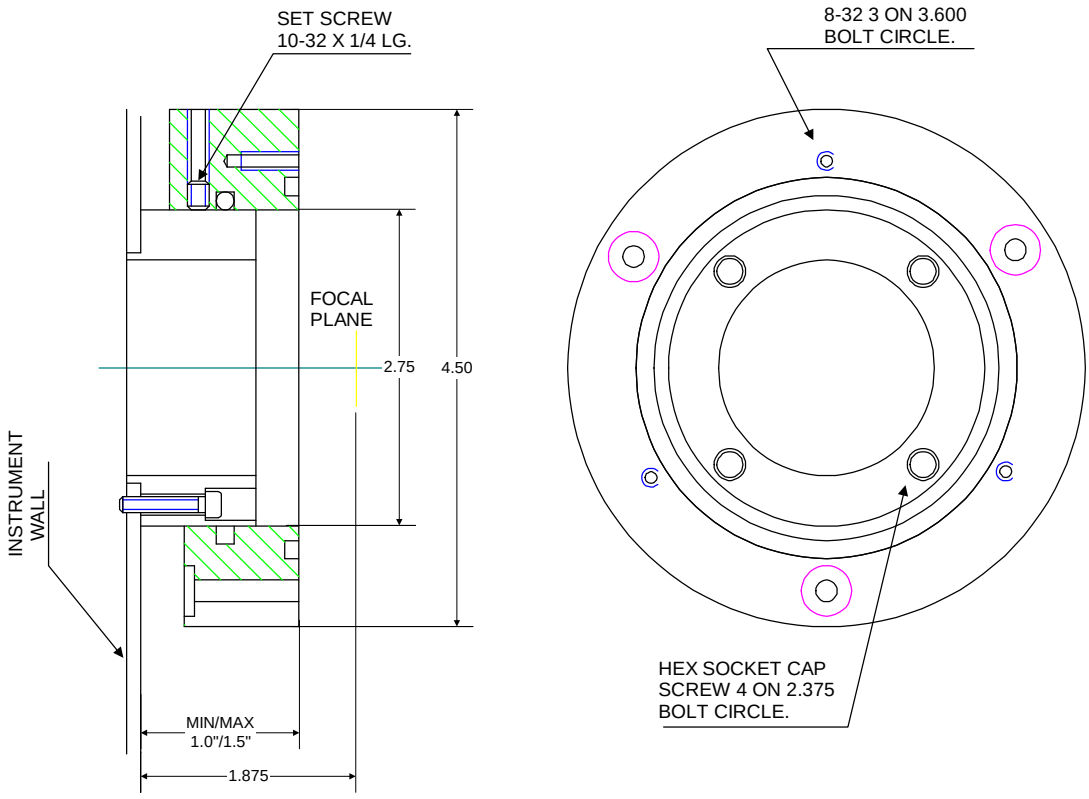


Figure 11: 33519 Spectrograph Adapter for 1681C

MAN 0094

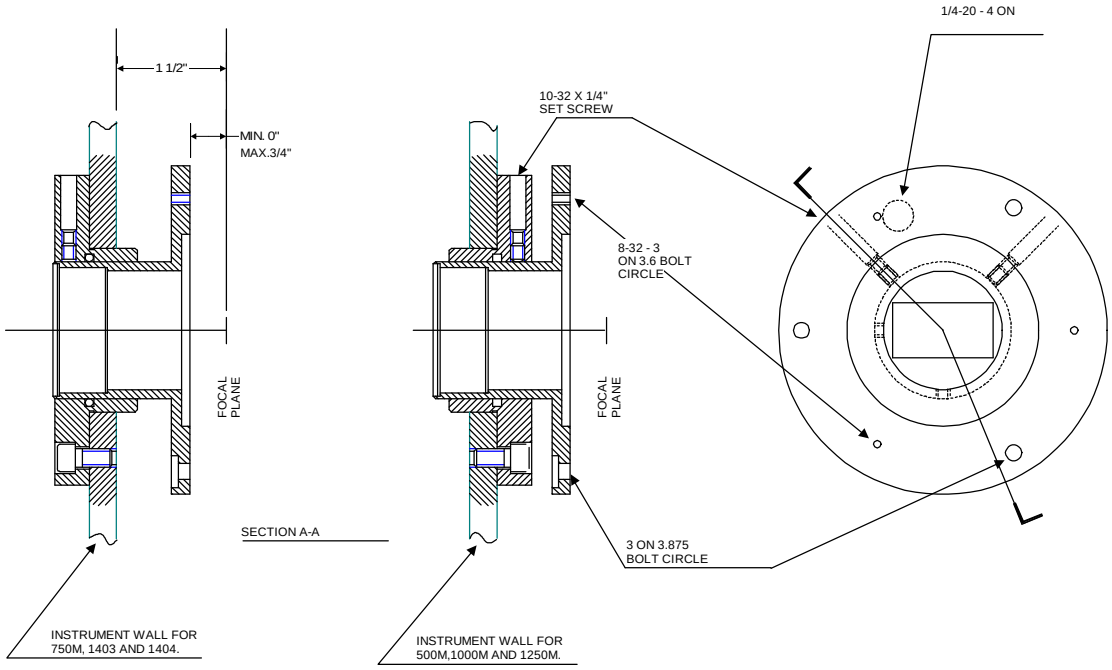


Figure 12: 1497 Array Adapter for 500M-1250M, 1403, 1404

MAN 0103

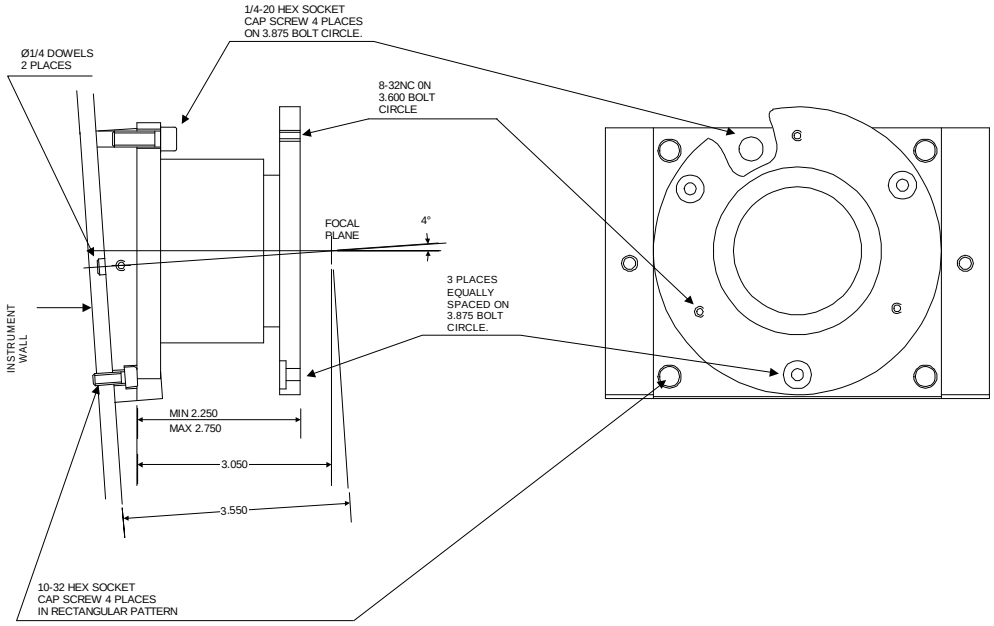
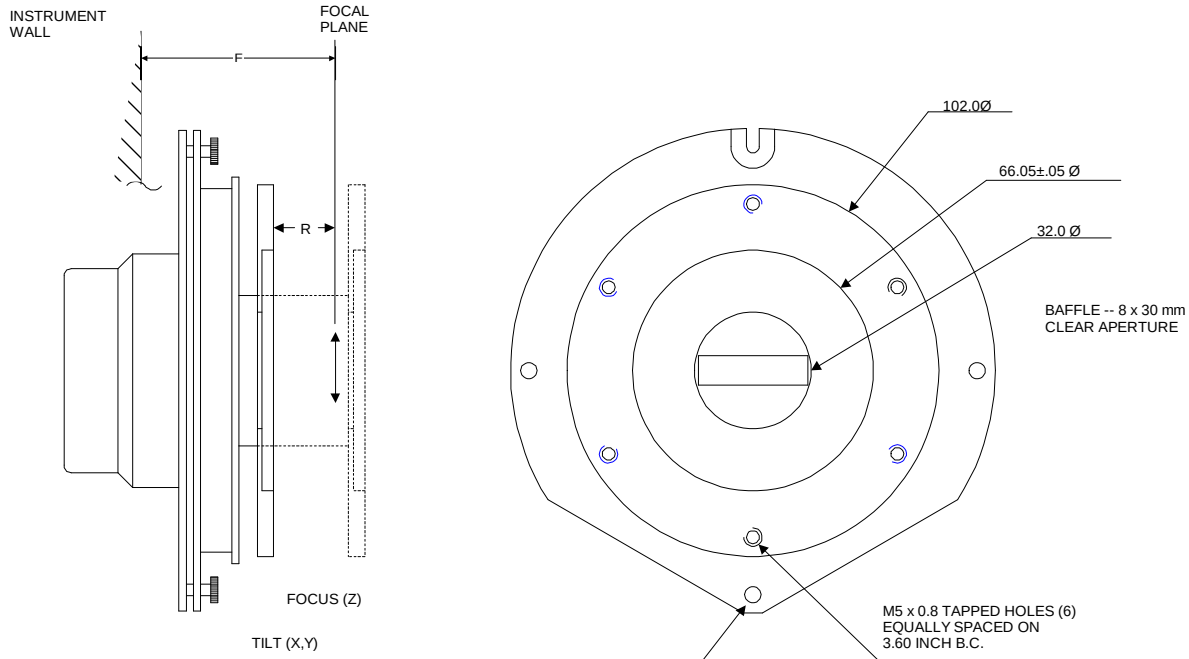


Figure 13: 32887 Spectrograph Adapter for 1877 Triplemate

MAN 0095



INSTRUMENT	NOMINAL F	RANGE R
HR 320	31.5	-2 to 11
HR 640	67.6	3 to 16
THR 640 *	33	0 to 13
THR 1000	33	0 to 13

NOTE: WHEN USING THR640 ACCESSORY #21.330.020
`FOCUSING SLIDE`, THE RANGE (R) BECOMES 0 to 28.

Figure 14: 303.50.713 Array Adapter for HR320, HR640, THR1000

MAN102

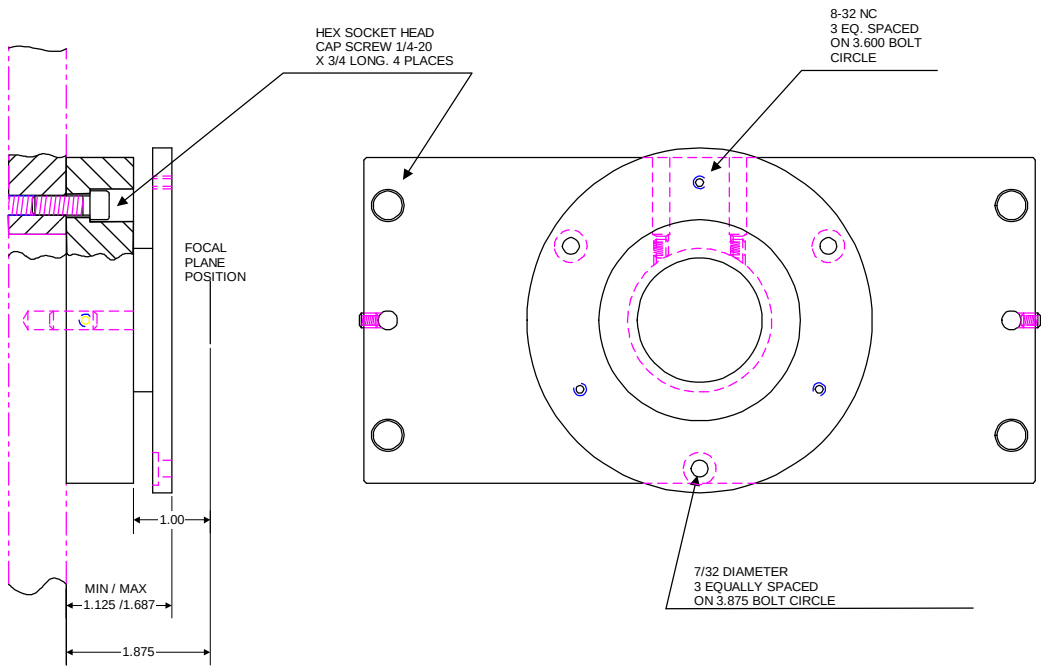


Figure 15: 35420 Adapter for 1269 Spectrometer

MAN 0100

Detector Positioning:

Note the mask on the face of the detector before mounting. This mask is offset to one side to accommodate the tilt if the focal plane for imaging spectrographs. For the HR460 and 270M, the aperture should be shifted towards the side that will be closest to the grating when mounted. If the mask is in the wrong position, carefully remove it (avoid disturbing the window) and reverse it.

The final focusing and alignment of the detector can only be accomplished with the software running. In this way, the signal detected can be monitored during the final positioning of the array. The shape of the signal can then be used as an alignment indicator. Install the cabling and shutter as explained in the following sections. The next section deals with software installation (page 28). Then see the Focusing and Alignment section (page 34) which explains the principles involved in positioning the detector array in the focal plane of the spectrograph. A general Alignment and focusing procedure is outlined there as well.

More specific instructions are given in the Software manual. See the Software Installation section of this manual as well (page 28). The spectrometer and its associated grating(s) are aligned together at the factory. Performance data in the form of calibration reports and plots are shipped with the instrument. Normally no adjustments to the grating mounts or other internal optomechanical components are needed to obtain the specified performance. If there is reason to suspect that the instrument has become misaligned, review the spectrometer manual. If help from Instruments SA is required, refer to page 42 for information about contacting ISA.

Mounting the Shutter:

The CCD shutter model number varies depending on the spectrograph used.

Shutter models 22.900.131, 22.900.129, & 21.384.710 for the S3000, U1000, & T64000 respectively.

Contact the ISA Service Department for assistance in installing the shutter onto the S3000, U1000 or T64000 Raman systems (see the Service Policy section page 41).

Shutter models 225MCD or 227MCD for the 270M Spectrometer.

The 225MCD shutter mounts outside on the axial (front) or lateral (side) entrance slit. Alternatively, the model 227MCD mounts inside the front axial entrance port. See the 270M manual for detailed installation instructions.

Connect the BNC-to-9-pin cable to the 9-pin connector on the cable coming from the CCD head. For the externally mounted 225MCD shutter, connect the BNC end to the BNC connector on the outside of the shutter mechanism. For internally mounted 227MCD shutters, connect the BNC end to the BNC connection inserted through the purge port.

Shutter model 22.900.109, for the CP200, HR320, THR640, THR1000, & THR1500 Spectrometers

Screw the shutter onto the 28 mm threaded adapter on the entrance slit of the spectrometer.

Connect the 32617 BNC-to-9-pin connector cable to the BNC connector on the shutter and to the 9-pin connector on the branch of the 35872 cable to the CCD head.

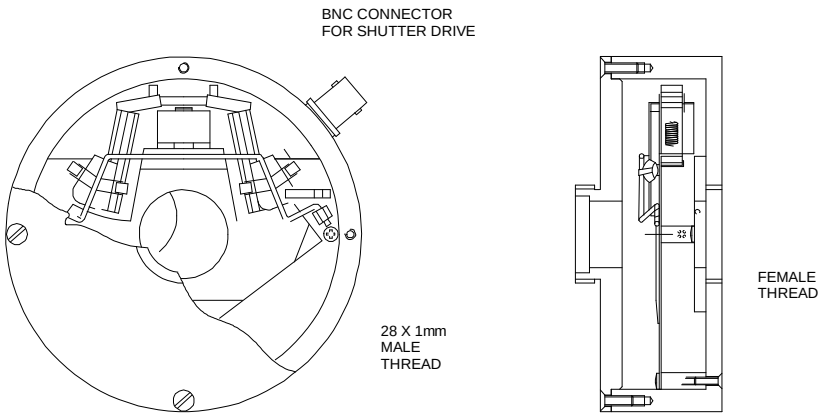


Figure 16: 22.900.109 Shutter for CP200 and HR-Series Spectrometers

MAN 0105

Shutter model 1425MCD(-series), for the 1681C, 340E/S, 500M, 750M, 1000M, 1250M, 1269, 1403, and 1404 Spectrometers.

Mount the model 1425MCD (See figure 17) shutter internally on the axial (front) slit. For the 1000M and 1250M, it can also be mounted internally on the lateral (side) entrance slit. For the axial (side) entrance of the 500M or 750M, use the 1424MCD-B. For dual entrance spectrometers, if shutters are required at both entrances, choose the correct shutter for the lateral slit, and add a 1425MCD-C for the axial slit. For all listed spectrometers *except* the 1681C and 340E, use two 1/4 -20 capscrews to attach the shutter support to the inside of the instrument wall. For the 1681C and 340E, use two 10-32 screws, and mount the shutter vertically, to avoid interference with the light baffle.

Remove the plug from the purge port of the spectrometer and using the wired BNC connector, screw the threaded end of the BNC connector into the purge port such that the wire hangs inside. Route the wires avoiding the optical path and moving parts inside the spectrometer. Connect the wiring from the shutter to the BNC connector.

Connect the 36217 BNC-to-9-pin connector cable to the BNC connector just installed, and to the 9-pin connector on the 35872 cable coming from the CCD head.

Shutter model 1825MCD for the 1877 Triplemate Spectrometer.

The 1825MCD mounts internally on the entrance slit of the spectrograph stage. Use the two 1/4 -20 capscrews included.

Remove the plug from the purge port of the spectrometer and using the wired BNC connector, screw the threaded end of the BNC connector into the purge port such that the wire hangs inside. Route the wires avoiding the optical path and moving parts inside the spectrometer. Connect the wiring from the shutter to the BNC connector.

Connect the 36217 BNC-to-9-pin connector cable to the BNC connector just installed, and to the 9-pin connector on the 35872 cable coming from the CCD head.

Shutter model 1625MCD for the 340E/S, 1681C Spectrometers

The model 1625MCD shutter mounts externally behind either the axial (front) or the lateral (side) entrance slit.

Connect the 36217 BNC-to-9-pin connector cable to the BNC connector on the shutter and to the 9-pin connector on the 35872 cable coming from the CCD head.

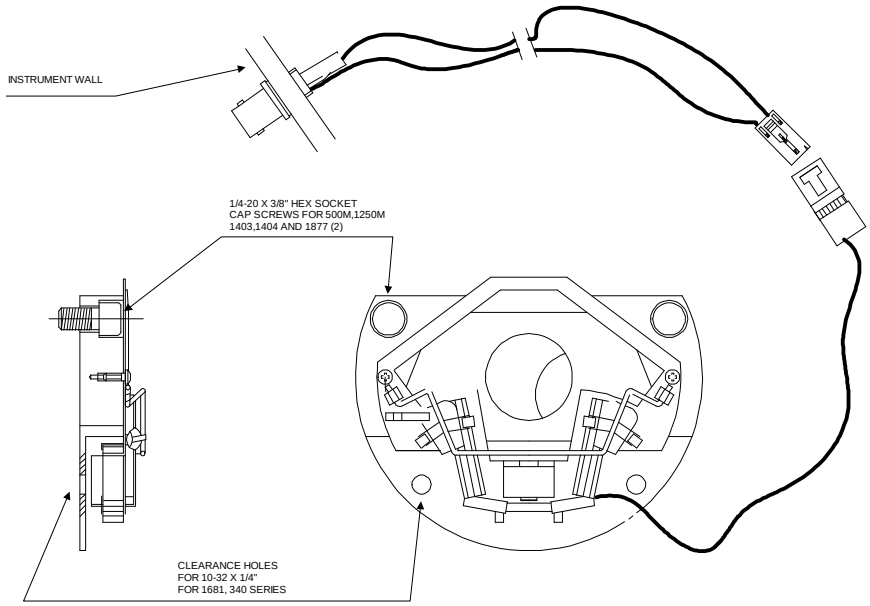


Figure 17: 1425MCD Shutter for 1681C, 340, 500-1250M, 1400 Spectrometers

MAN 0106

Electrical Connections for CCD-2000:

Warning: Do not disconnect system cables while any components are powered on. The resulting electrostatic discharge may damage the electronics.

1) Switch the power off at the rear panel power input module of the Detector Interface Unit. Turn off the computer as well. Using the 99603 twisted pair ribbon cable, connect the "computer" connector of the Interface Unit (see Figure 7) to the D-shell connector on the PC communications card installed in the computer.

2) With the CCD2000 power off, connect the female 37-pin connector on the Interface Unit to the 37-pin connector on the 35872 cable.

3) For thermoelectrically cooled heads a 9 pin male to female 37661 cable is provided to connect the cooler power supply in the CCD2000 to the head.

   For the high performance air and water cooled heads, the connector on the CCD-2000 is female and the connector on the head is male. For the Mini head, this is reversed. The power requirements of the Mini head's cooler differ from the others. This connector arrangement prevents damage due to mismatching.

4) Remove the grounding connector from the 25-pin connector on the Spectrum One detector head. Connect the 35872's 25-pin connector of the adapter cable to the CCD, first touching the cable connector shield to the metal case of the head to drain any static charge.

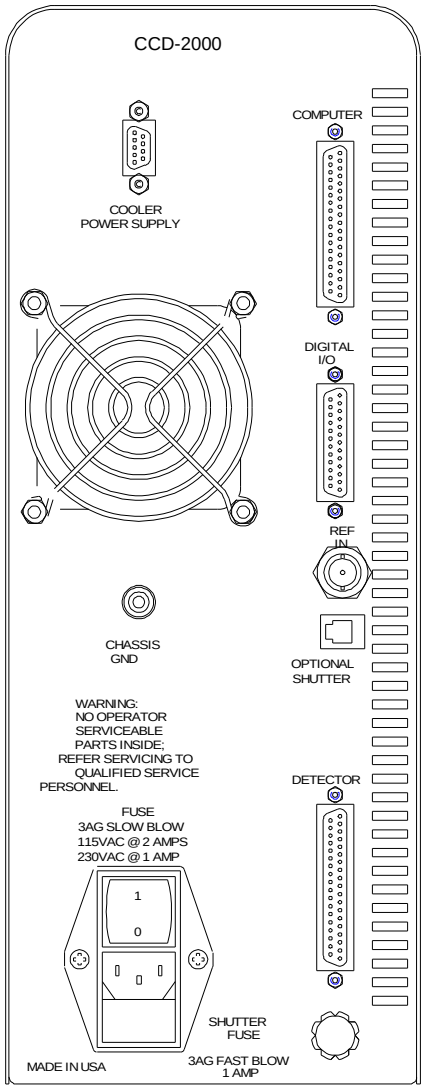


Figure 7: Detector Interface connections

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NOTE: To prevent Electrostatic Discharge (ESD) damage, insert the grounding plug into the connector on the detector head whenever the CCD head is disconnected.

5) The 9-pin shutter connector that branches off the same 35872 cable attaches to the shutter after the shutter Installation is completed. See page 28 for further information.

Electrical Connections for CCD-3000:

Warning: Do not disconnect system cables while any components are powered on. The resulting electrostatic discharge may damage the electronics.

1) Switch the power off at the rear panel power input module of the Detector Interface Unit. Turn off the computer as well.

2) With the CCD3000 power off, connect the IEEE-488 connector in the host computer to the IEEE-488 connector on the controller.

3) Remove the grounding connector from the 25-pin connector on the Spectrum One detector head. Connect the 35872's 25-pin connector of the adapter cable to the CCD, first touching the cable connector shield to the metal case of the head to drain any static charge.

NOTE: To prevent Electrostatic Discharge (ESD) damage, insert the grounding plug into the connector on the detector head whenever the CCD head is disconnected.

4) The 9-pin shutter connector that branches off the same 35872 cable attaches to the shutter after the shutter Installation is completed. See page 28 for further information.

SOFTWARE INSTALLATION:

The controlling software must be configured for a CCD and installed properly in order for the Spectrum One to operate. When the system is ordered with the computer, the software will be installed and tested at the factory. In those cases where the user must install the software, The configuration files for the system are provided on the installation diskettes. Simply follow the installation directions in the manual provided with the software.

The software includes the Spectrum One Initialization routine used to monitor the chip temperature as the head cools to its specification.

For SpectraMax for Windows Software:

- Install SpectraMax for Windows software on the computer. Follow the procedure in the SpectraMax for Windows manual.

For SpectraMax (DOS) Software:

- Install SpectraMax software on the computer. Follow the procedure in the "Getting Started" section of the SpectraMax software manual.
-

TURNING THE SYSTEM ON

There is a particular sequence that must be followed for activating the Spectrum One system. It is important that LN_2 is not filled before the power up sequence is completed. This insures that the CCD will be initialized properly. The system will not function properly otherwise.

Caution: The Detector Interface Unit must be turned on and initialized before liquid nitrogen is added to the dewar.

In Case of Power Interruption:

For thermoelectrically cooled heads, restart as normal. For LN_2 cooled heads, if power is interrupted while the detector is cooled the system can be restored to normal operation by performing the following steps:

- Repower the system as usual
- Reinitialize the CCD
- Note that the sensor may be at a *lower* than normal operating temperature due to loss of thermostat control while unpowered. Allow enough time for the sensor to return to normal operating temperature.
- Run a series of full area readouts with short integration time. This will flush most trapped charges from the CCD sensor. For most cases, normal operation can be resumed at this point.
- For those cases where very long integration times are used, an increase in dark charge may be noticeable. If the effect is small and subtractible, proceed as normal, but take background spectra at more frequent intervals. If this effect happens to be large compared to the desired signal, the dewar should be allowed to warm to room temperature and then reinitialized to clear all trapped charges.

For SpectraMax for Windows Systems:

Turn on the spectrometer and its associated SPEX/JY 232/488 interface, DataScan or SpectrAcq controller if so equipped, then the CCD2000 or CCD3000 Detector Interface Unit, and computer. From the Windows program group "SpectraMax for Windows," double-click the **HWINIT** icon to start the DOS program that initializes the CCD hardware (HWINIT not present for CCD3000

controller). The CCD Initialization routine will monitor the temperature while the CCD is cooling to operating temperature. For LN_2 heads, add liquid nitrogen as per the instructions on page 32. Then, continue with the CCD Initialization as per the instructions on page 31.

For SpectraMax (DOS) Systems:

Turn on the spectrometer and its associated SPEX/JY 232/488 interface, DataScan or SpectrAcq controller if so equipped, then the CCD2000 or CCD3000 Detector Interface Unit, and computer and type "SM <Enter>"at the DOS prompt for the drive where SpectraMax is loaded. The SM.BAT batch file will run the HWINIT program to initialize the CCD and load SpectraMax. The CCD Initialization routine will monitor the temperature while the CCD is cooling to operating temperature. For LN2 heads, add liquid nitrogen as per the instructions on page 32. Then, continue with the CCD Initialization as per the instructions on page 31.

For Systems with SpectraLink Controllers:

Turn on the SpectraLink, the Spectrum One Detector Interface Unit, and computer and type SpectraMax <enter> at the DOS prompt for the drive where SpectraMax is loaded. The SM.BAT batch file will run the HWINIT program to initialize the CCD and load SpectraMax. The CCD Initialization routine will monitor the temperature while the liquid nitrogen is added to the dewar and the CCD is cooling to operating temperature. Add liquid nitrogen as per the instructions on page 32. Then, continue with the CCD Initialization as per the instructions in the next section.

INITIALIZATION (FOR CCD2000 CONTROLLER):

The HWINIT (HardWare INITialization) program sets up a number of operating parameters in the CCD controller. Then it monitors the two temperature sensors in the CCD head. One sensor indicates the temperature of the liquid nitrogen or the warm side of the Thermoelectric cooler (SINKTMP). The other monitors the temperature of the metal block to which the CCD is mounted to give the temperature of the CCD itself (CCDTEMP1).

```
Type E when a stable temperature is reached!

SINKTMP   33354  287   80  300    .           |  .
CCDTEMP1  33202  210  125  300    .    |         .

Average Sinktemp = 286.9
Average Ccdtemp  = 209.5
```

HWINIT Temperature Display

On the computer screen, two lines of data appear, one for each of the sensors. The data in the first two columns next to these labels fluctuates: the first value is the raw signal count from the sensor and the second value is the sensor temperature in Kelvin. The numbers in the last two columns are the minimum and maximum Kelvin temperatures for the temperature indicator scale at the right.

For LN_2 heads, it will take approximately 30 to 40 minutes from the beginning of cooling the detector until it reaches its target temperature. Thermoelectrically cooled heads will reach operating temperature in 15-20 minutes. This time will also vary depending on the size of the chip. Note that for best results in the most demanding measurements, it is best to allow 60 to 90 minutes for the CCD chip to stabilize completely.

The initialization routine will continuously display the temperature. When the second value in the row labeled CCDTEMP1 has stabilized at or near the target temperature, type “E” to exit the temperature monitoring loop and continue with the rest of the HWINIT program.

Exiting before the temperature is stabilized may cause errors in data collection. The CCD Initialization program sets the operating parameters of the CCD based on the assumption that it has reached operating temperature, and that the head will remain stable at that temperature maintained by the detector interface unit. Changes in temperature after the parameters are set will affect the data. If there is reason to believe that changes in the operating conditions of the lab may have affected the temperature of the CCD, re-initialize the detector.

Periodic Initialization:

It is suggested that the CCD Initialization program be run once a day, prior to taking any critical measurements. In this way, adjustments can be made to the CCD settings for any variations in environmental conditions or dewar temperature. Refer to previous section, Initializing the CCD.

LIQUID NITROGEN PRECAUTIONS

Warning: Liquid Nitrogen requires special handling. Read this section carefully before filling the dewar.

Ventilation:

In confined spaces lacking adequate ventilation, nitrogen gas can displace air to the extent that it can cause asphyxiation. Always use and store liquid nitrogen in well-ventilated spaces.

Extreme Cold:

The boiling point of liquid nitrogen at atmospheric pressure is 77.3 K (about -156^{o}C). This extreme cold can cause tissue damage similar to a severe burn. Therefore, exposure of the skin or eyes to the liquid, cold gas, or liquid-cooled surfaces must be avoided.

The liquid should be handled so that it will not splash or spill. Gloves impervious to liquid nitrogen and goggles should be worn when handling the liquid. Feet can be protected by wearing rubber boots, with trousers (without cuffs) on the outside.

Storage and Transfer:

Liquid nitrogen should always be stored in vacuum-insulated containers, which should be loosely covered but not sealed. Covering prevents moisture condensing out of the air to form ice which may cause blockage. Sealing results in pressure buildup. **DO NOT ATTEMPT TO SEAL THE MOUTH OF THE DEWAR!**

The gas-to-liquid volume ratio is about 680:1. All containment vessels must therefore be fitted with exhaust vents to allow evaporating gas to escape safely. If these vents are sealed, pressure will build up rapidly and may result in the fracture of the containment vessel.

LN_2 Filling Instructions:

Caution: The Spectrum One Detector Interface Unit must be turned on and the HWINIT program must be running before the dewar is filled.

If the system is off, turn on the system following the “Turning the System On” procedure as outlined on page 29.

In the event of power failure, turn the unit off, let the dewar warm to room temperature, then start over with the “Turning the System On” procedure.

Take care not to overfill. If the liquid nitrogen is spilled on apparatus around or below the detector, the resulting thermal shock may have a detrimental effect.

Using a pressurized storage vessel:

Remove the cap and insulating plug at the top of the detector dewar, insert the fill tube, and let the nitrogen flow into the dewar.

Using a funnel and transfer dewar:

Insure that the funnel has ribs to provide gaps to vent the boiled off vapor as the liquid nitrogen is added. Set the funnel into the mouth of the dewar. Pour the liquid nitrogen into the funnel slowly.

The dewar is full when the liquid nitrogen reaches the bottom of the narrow neck of the dewar. A probe such as a clean wooden dowel may be inserted and removed to reveal a frost line indicating the nitrogen level.

Periodic Filling:

The larger, 2.8 liter dewar permits continuous cooled operation of the CCD by virtue of its 72-hour hold time. The smaller, 1 liter dewar, with a hold time of 24 hours, is designed for more intermittent operations.

Note: The electronics must be activated in the proper sequence (computer, then Detector Interface Unit) before liquid nitrogen is added to the dewar.

Replace the cap when the dewar is full. The cap is insulated to help extend the interval between fills. It also minimizes moisture condensation into the dewar. The loose fit of the cap prevents pressure buildup in the dewar by allowing evaporating nitrogen to escape.

When filling the dewar, an initial period of nitrogen boiling and overflow occurs until the internal components of the dewar have cooled to liquid nitrogen temperatures. After this initial boil-off period, refill the dewar as needed to extend the cold temperature hold time.

FOCUSING AND ALIGNMENT:

Once the Spectrum One head is mounted and the system connected, the position of the head must be adjusted so that the CCD sensor lies at the instrument focal plane, and that the spectral slit images are aligned with the pixel columns.

Note: The head must first be cooled to operating temperature before the CCD can be focused and aligned.

With SpectraMax for Windows software:

1) Attach a spectral line source, such as a mercury lamp, to the instrument entrance slit. Reduce the slit width to make the image of the slit as narrow as possible on the detector. This will allow determination of the best focus.

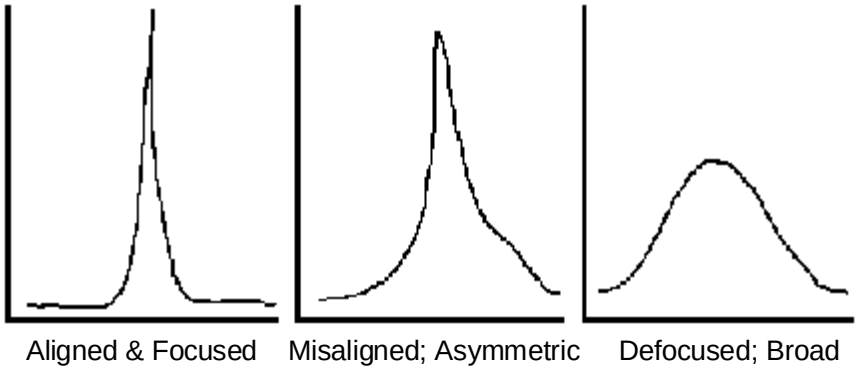


Figure 17: Examples of peaks during Alignment and Focusing

2) Start the RTD portion of the software.

3) Set the “Integration Time" to 0.1 second, and select continuous spectrum acquisition and screen update by pressing the Up Arrow on the Spectrometer Step Control.

4) Begin live acquisition.

5) Observe the spectra. A focused, aligned CCD will provide a distinct symmetrical peak of large amplitude. The peak should be less than or equal to 5 pixels wide across the Full Width of Half the Maximum height (FWHM). Asymmetry of the peak is a sign that the slit image is not aligned to the pixel columns; diminished shape and magnitude are symptomatic of defocusing. (Figure 17)

6) Loosen the set screws on the adapter barrel. Adjust the CCD sensor plane position by moving the head in and out with respect to the exit port. (The CCD plane is approximately

9.5 mm, or 3/8", behind the mating surface of the detector head's mounting flange.) The CCD orientation is adjusted by rotating the detector head to the right or left in the exit port.

7) Verify that the alignment is good by acquiring an image. When the output is imaged, alignment results in an upright, sharp image of a spectral diffraction pattern on the computer.

8) Tighten the set screws in the outer adapter barrel once the CCD has been aligned and focused.

To optimize the linearization of the system, refer to the SpectraMax for Windows software manual.

With SpectraMax for DOS software:

Refer to the CCD Acquisition section of the SpectraMax for DOS Manual for complete information and instructions.

SYSTEM OPTIMIZATION:

After completing the installation, some applications demand further, special attention to assure that the CCD detection system is yielding the best possible signal to noise ratio. The following topical discussions may be helpful in extracting optimal performance from the system.

Optical Optimization:

In many cases, it may be a simple matter to increase signal strength at the detector by increasing optical power at the source. Reducing losses by improving optical coupling from the source to the sample and / or from the sample to the spectrograph entrance slit can also yield dramatic results.

Try to reduce the possibility of stray light entering the system. Check for light leaks by darkening the room or by covering any open segments of the optical system. Use an opaque black cloth to cover portions of the system. Further isolation of leaks may be possible by shining a flashlight at suspected portions of the optical system while monitoring the signal.

Spatial Optimization:

Often the optical signal of interest that is imaged on to the CCD array occupies only part of the total array area. With the Spectrum One, there is no need to collect signal from the entire area. With Area selection, one may select a reduced portion of the active area, and in so doing, reduce the dark signal and its associated noise. Susceptibility to cosmic rays will be reduced proportionately as well.

The best way to optimize the active area to correspond to match the portion where the signal is located is to acquire a full-chip image of the signal. If the actual signal is too weak, try to approximate the signal using the exact same collection optical setup, but substitute a brighter signal. Refer to the software manual for instructions on defining the active area(s).

Reducing the Number of Conversions:

Each time an analog to digital conversion is made, some noise is introduced. For spectra that are imaged as essentially vertical slit images on the array, the pixels illuminated in their vertical columns can be binned into superpixels, to be combined before conversion to datapoints. Likewise, when spectral resolution is not a limiting factor, the signals can also be horizontally binned into two dimensional superpixels. The limit on this is that the combined signal intensity for the most intense superpixel should not exceed the ADC limit. Refer to the software manual for instructions about binning.

Increasing integration time per readout will improve the S/N through signal averaging.

If the signal out of range error is never received, increase the detector gain. Increase the gain to the highest range where the signal out of range error is not received. This will more efficiently match the signal to the available dynamic range.

When signal levels in some pixels are at or near the saturation level, acquiring a series of integrations of shorter duration and summing them digitally provides a means to avoid saturation.

Environmental Noise Reduction:

Because of the extreme low internal noise characteristics of the liquid nitrogen cooled CCD, special precautions to minimize noise pickup from external sources is required.

Important: Do not place a computer monitor on or near the CCD Detector Interface Unit. The because of the extreme sensitivity of the signal electronics required to take full advantage of the CCD's low noise, electromagnetic noise radiated by the monitor may be picked up. This may be seen in the spectral data as an increase in read-out noise.

Although shielded, in the limit, the CCD detector head and cables are sensitive to electromagnetic fields. For best results the CCD system should be isolated from devices generating such fields.

- Electromagnetic interference (EMI) from a variety of sources may be picked up by the sensitive input channels. Try isolating any other apparatus suspected to be a noise source by turning it off while monitoring the signal in real time. If possible, connect them to power circuits separate from the CCD2000 or CCD3000.
- Note that the room lights may radiate EMI based on the (50 or 60 Hz) power line frequency. A battery powered flashlight will not.
- If noise is reduced by turning off the spectrometer power switch, rearrange power connections to be sure the spectrometer, source, and detector are tied to the same ground and, if possible, the same power circuit.
- A redundant grounding strap connected from the detector to a centrally located system ground may help. The binding post on the CCD2000 and CCD3000 rear panel adjacent to the power input module is provided as a chassis ground point. Ground loops and electromagnetic interference can be challenging problems. The best place to attach a ground is usually discovered by a trial and error process. In extreme cases, the best approach is to patiently experiment by trying various combinations of grounding connections. As a general rule, try to keep ground wires short, make tight connections, avoid painted, coated, and anodized surfaces when possible. Consider a "star ground" of redundant ground wires radiating from a single, central location, preferably connected to a grounded metal table surface under the system.

- Adding redundant ground wires to various points in the system sometimes helps. Guard against the creation of ground loops that may occur when power grounds and signal grounds are connected. Also keep digital grounds and their typical high frequency noise separate from signal ground.
- In extreme cases, such as working with or around high powered pulsed lasers or other high energy apparatus, it may be helpful to construct RFI / EMI shields or cages to contain the noise at its source, or to isolate the detection system from the noise. In these cases, colleagues who are working with a similar apparatus may be your best resource for noise control suggestions.

Should the CCD system detect high levels of noise, a grounding strap connected from the detector head to a ground may help. It is important to avoid disturbing the screws that hold the vacuum sealed flanges together. The best place to attach a ground varies depending on the type of head used. For side looking LN_2 heads, use the threaded hole at the bottom of the dewar. For down looking LN_2 heads, use one of the mounting screws on the 25 pin connector. For water or air cooled, use one of the mounting screws on the 9 pin connector on the head.

Re-Initialization of the CCD2000 controller:

The CCD may be operated to acquire non-critical data or perform setup functions before the temperature of the chip is stabilized. While running the HWINIT program during the startup procedure, simply exit (type “e”) at any temperature, and enter the software. When the CCD’s actual temperature changes from the initialized temperature, the baseline dark signal is affected. When the baseline either falls below -400 or rises above 2000 counts, or when ready to acquire critical data, re-initialize the detector. The need to re-initialize will be less frequent as the detector approaches its target temperature.

Once the CCD has reached its final stabilized temperature (about 60 to 90 minutes after turn on), the baseline will no longer drift. At this time, to re-initialize the CCD, exit out of the software, run HWINIT, and return to the software. (In SpectraMax for DOS, this can be set up as a Utility feature on the pull-down menu eliminating the need to exit the software.)

In this way, the initialization values are updated, and the signal processing will be optimized.

Re-Initialization of the CCD3000 controller

No initialization is necessary.

USER TROUBLESHOOTING:

The Spectrum One CCD detection system is designed to perform for years with minimal maintenance.

The detector head is evacuated or purged, and eventually will need re-pumping or re-purging. For evacuated heads, the level of vacuum required is beyond the capabilities of mechanical vacuum pumps. User re-pumping is not recommended. The user's responsibility in this regard is simply to monitor the operating temperature on a periodic basis. Monthly checking by observing the HWINIT program's temperature status display will indicate the operating temperature. Refer to the Specifications listed on page 14 for the temperature appropriate for each type of CCD head. When the cooling circuitry can no longer maintain the specified temperature, contact the factory for assistance.

If the shutter should fail to actuate, check the shutter fuse. For CCD2000 controllers, the fuse holder is mounted in the rear panel. If blown, replace with a 1 amp fast blow fuse. For CCD3000 controllers, the fuse holder is inside the CCD controller**. Use extreme caution when replacing the fuse.** Turn off the power to the CCD controller, but keep the line cord connected to utilize the grounding connection it provides. **Observe antistatic precautions by wearing a grounded wrist strap and working on a grounded surface.** Remove the top cover and find the fuse holder on the left hand side of the bottom board, near the front panel. If blown, replace with a 1 amp fast blow fuse.

Should the CCD system detect high levels of noise, a grounding strap connected from the detector head to a ground may help. It is important to avoid disturbing the screws that hold the vacuum sealed flanges together. The best place to attach a ground varies depending on the type of head used. For side looking LN_2 heads, use the threaded hole at the bottom of the dewar. For down looking LN_2 heads, use one of the mounting screws on the 25 pin connector. For water or air cooled, use one of the mounting screws on the 9 pin connector on the head.

If the signal is still too noisy:

- Try to increase the strength of the optical signal at the detector.
- Do what you can to eliminate or reduce the non-signal light that is allowed to enter the spectrograph entrance slit, whether on the optical axis or not.
- Check for light leaks as suggested under "Background signal too high" in this section.
- Refer to System Optimization on page 38 for more help.

- If noise is reduced by turning off the spectrometer power switch, rearrange power connections to be sure the spectrometer, source, and detector are tied to the same ground and, if possible, the same power circuit.

- Adding redundant ground wires to various points in the total system often helps. Please understand that ground loops and electromagnetic interference can sometimes be challenging problems. In extreme cases, the best approach is to patiently experiment by trying various combinations of grounding connections. As a general rule, try to keep ground wires short, make tight connections, avoid painted, coated, and anodized surfaces when possible. Consider a "star ground" of redundant ground wires radiating from a single, central location, preferably connected to a grounded metal table surface under the system.

- In extreme cases, such as working with or around high powered pulsed lasers or other high energy apparatus, it may be helpful to construct RFI / EMI shields or cages to contain the noise at its source, or to isolate the detection system from the noise. In these cases, colleagues who are working with similar apparatuses may be your best resource for noise control suggestions.

If one side of the array has no sensitivity to signals:

The mask on the face of the detector may be offset in the wrong direction. Remove the detector head from the spectrograph port to check. This mask is offset to one side to accommodate the tilt if the focal plane for imaging spectrographs. For the HR460 and 270M, the aperture should be shifted towards the side that will be closest to the grating when mounted. If the mask is in the wrong position, carefully remove the 8 screws (avoid disturbing the window) and reverse it. Then proceed with remounting the head following the instructions beginning on page 17.

Using the MCR 2000 X 800 Pixel Array

Due to the vast number of data points that are collected with this array it is recommended that the computer has at least 16 MB of expanded memory (RAM). To fully utilize this memory, particularly when running SpectraMax for DOS, the following lines should appear in the CONFIG.SYS file:

```
DEVICE=C:\DOS\EMM386.EXE RAM D=64 H=255
```

If the CONFIG.SYS file already has such a line, make sure the values for D and H are correct. Note that there is no set value for the amount of RAM made available to EMM386. EMM386 needs to be able to use as much memory as possible. Make sure that EMM386 makes at least 12 MB available in Free Expanded Memory.

SERVICE POLICY:

If you need assistance in resolving a problem with your instrument, contact our Customer Service Department directly, or if outside the United States, through our representative or affiliate covering your location.

Often it is possible to correct, reduce, or localize the problem through discussion with our Customer Service Engineers.

All instruments are covered by a warranty. The warranty statement is printed on the inside back cover of this manual. Service for out-of-warranty instruments is also available, for a fee. Contact ISA for details and cost estimates.

If your problem relates to software, please verify your computer's operation by running any diagnostic routines that were provided with it. If there is a support diskette provided, refer to the manual for that diskette, and follow the troubleshooting procedures. Be ready to provide version numbers for the DOS that you are using, as well as the software version and firmware version of any controller or interface options in your system. The software version can be determined by reading the version from the welcome panel that is displayed when the software is loaded. Or select the software name at the right end of the menu bar and click on “About” to view the same panel. Also knowing the memory type and allocation, and other computer hardware configuration data from the PC's CMOS Setup utility may be useful.

In the United States, customers may contact the Customer Service department directly:

- By phone at (908) 494-8660 ext. 186
- The Service fax numbers are (908) 549-2571 for Raman, 549-5157 for Fluorescence, or 549-9309 for Systems Group.
- E-mail us at Systems@isainc.com
- Or you may write to:

  Instruments SA, Inc.
  Customer Service (Specify Raman, Fluorescence, or Systems Group)
  3880 Park Avenue
  Edison, N.J. 08820 U.S.A.

From other locations worldwide, contact the representative or affiliate for your location.

If an instrument or component must be returned, the method described on the following page should be followed to expedite servicing and reduce your down-time.

Return Authorization:

All instruments and components returned to the factory must be accompanied by a Return Authorization Number issued by our Customer Service Department.
To issue a Return Authorization number, we require:

- The model and serial number of the instrument
- A list of items and/or components to be returned
- A description of the problem, including operating settings
- The instrument user's name, mailing address, telephone, and fax numbers
- The shipping address for shipment of the instrument to you after service
- Your Purchase Order number and billing information for non-warranty services
- Our original Sales Order number, if known
- Your Customer Account number, if known
- Any special instructions

APPENDIX A: GLOSSARY

The discussion of detection with charge coupled devices requires some familiarity with the terminology used. This section includes definitions specific to this context for some familiar terms, as well as several unique terms, abbreviations and acronyms.

ADC:

An Analog to Digital Converter (ADC) converts a sample of an analog voltage or current signal to a digital value. The value may then be communicated, stored, and manipulated mathematically. The value of each conversion is generally referred to as a datapoint.

Backthinning:

The depletion layer of a CCD (where the photoelectric effect occurs) is normally partially obscured under the electrode gates, which are formed in layers above the depletion layer. This is due to the constraints of the chip fabrication process. The substrate (or back) of a CCD chip can be etched down to be very thin. Then the chip is mounted so that the signal light is incident on the back rather than the front. The chance a photon has of reaching the depletion region is greater. Thus, the Quantum Efficiency is higher. See the graphs on page showing the greater QE of the backthinned CCD.

Binning:

The charges of adjacent pixels can be combined in the readout register cell for that column or row. This combining is called binning. Binning can be used to select only the illuminated pixels. Binning enables adjustment of the effective detector height from one pixel up to the full height of the CCD. More than one binned area can exist in a given readout.

The signal level increase is directly proportional to the number of pixels binned. However, shot noise only increases as the square root of the number of pixels (Felgett's S/N Advantage). Thus, signal to noise ratio is improved. Readout- associated noise is also reduced because the total signal from the binned number of pixels is combined into a single analog to digital conversion.

Binning also enables selective readout of multiple spectra. The signals from several samples can be optically collected simultaneously and imaged to vertically separated parts of the spectrograph entrance slit. This will result in vertically separated spectra imaged across the CCD. By binning the heights of these spectra, each binned area can be captured as a separate spectrum from the same readout cycle. The dark signal from unused pixels between the spectra can be discarded. Signal/Noise is improved by discarding dark signal from non-illuminated pixels.

Charge Coupled Device:

The CCD is a solid state photodetector array made of silicon. It is essentially one continuous photosensitive material. Individual pixels or picture elements are defined by a grid of three electrode gates in the X and Y directions. The charge is collected under the gate with the greatest potential. During the readout cycle, the voltages applied to the gate electrodes are manipulated to move the charge across the pixels to the output register at the edge of the array. In contrast, PMT's and other single channel detectors can measure only one intensity at a time. PDA detectors measure both intensity and wavelength. The CCD simultaneously measures intensity, wavelength and position differences projected along the height of the spectrograph image plane.

Charge Transfer Efficiency (CTE):

The percentage of charge moved from one pixel to the next is the charge transfer efficiency. The CCD has a high CTE if the pixels are read out slowly. As the speed at which the charge is transferred is increased, increasing amounts of the charge is left behind. The residual charge combines with the charge of the next pixel as it is moved into the cell. Therefore, using too high a transfer rate deforms the image shape; it smears the charge over the pixels that follow in the readout cycle. Temperature also affects CTE. Below -140°C the movement of the charges becomes sluggish, and, again, the image becomes smeared.

Correlated Double Sampling:

This is a technique used to increase the signal to noise ratio of each datapoint detected. Minute charges are unavoidably retained in the readout register between one sample and the next. Even though the readout register is reset after each point is read, some charge will persist. At the extremely low signal levels that are typical for cooled CCD detection, these charges are significant. By sampling this retained charge, amplifying and inverting it, it can be canceled by combining it with the actual signal which is amplified, but not inverted. The combined signal is then passed to the ADC to be processed as a datapoint. This process ensures that only the charge due to the signal in each pixel is measured.

Cosmic Ray Events:

Cosmic Rays are high energy particles from the sun. Although they penetrate all detectors, their effect usually is masked by dark current. The dark signal of an LN_2 cooled CCD is so low that cosmic rays may be detected. In the active area of a typical array, about 10 events per minute may occur. Compared to very weak signals, detected cosmic ray events can be quite distracting. To minimize the effects of cosmic rays, one can use the smallest section of the chip that the experiment allows, and use the least integration time possible. **Variable Gain** can help to reveal weak signals. Mathematical treatment of the data can also be used to

remove the spurious spikes in spectra. Refer to the software manual for more about cosmic ray spike removal.

Dark Signal:

Dark signal is generated by thermal agitation. This signal is directly related to exposure time and increases with temperature. The dark signal doubles with every 7^{o}C increase in chip temperature above -25^{o}C. The more dark signal, the less dynamic range for experimental signal. This signal accumulates for the entire time between readouts or flushes, regardless of whether the shutter is open or closed. Dark signal is also generated during the charge transfer cycles of the CCD.

Dynamic Range:

The **Dynamic Range** is the ratio of the maximum and minimum signal measurable. The dynamic range of the chip can be greater than that of the system which is limited by the **ADC**. A 16 bit ADC limit is 65,535 (2^{16}-1) counts. A 14 bit ADC is limited to 16,383 counts. **Variable Gain** can be used to shift the ADC range to match the potential well capacity or signal levels of a given spectral measurement. In this way, stronger or weaker signals can be accommodated with optimal Dynamic Range.

On a pixel by pixel basis, the most intense detectable signal, the saturation level, is the lesser of the **Potential Well Capacity** of the pixel or the ADC maximum limit. When pixels are binned, individual pixels within a binned area may saturate if the intensity is concentrated. Also, the well capacity of the readout register will limit the total signal that can be binned from a given row or column of a binned area.

The weakest detectable signal is limited by the **Dark Level** plus the **Readout Noise**.

Electrons/Count:

Electrons per count is a value indicating how many electrons are needed to be identified by the **ADC** as the smallest measurable unit, or Count. The total “Counts” of a given datapoint are comprised of electrons from a variety of sources, including: Photoelectrons (signal), Dark Level, Read Out Noise, Bias Level, and Amplifier Noise.

Felgett's Advantage:

Multichannel detection provides an improvement in signal to noise ratio, as compared to single channel (scanned) spectral detection. Because the multichannel detection acquires a number of spectral elements simultaneously, the S/N is improved by a factor proportional to the square root of the number of channels acquired.

Flush:

To reduce noise and maximize dynamic range at the CCD, the dark charge that has accumulated on the chip can be rapidly removed by flushing. The effect of flushing the array is similar to a readout cycle in that the charges are cleared from the pixels. But a flush dumps the charges without conversion. A flush is much faster than a readout. Flushing is only necessary when there is an appreciable time between readouts.

Full Well Capacity:

Full well capacity is the measure of how much charge can be stored in an individual pixel. This specification varies for each chip type. It depends on the doping of the silicon, architecture and pixel size. The quantum well capacity is usually around 300,000 electrons. The greater the well, the greater the **Dynamic Range**. A chip with a larger full well capacity can record a higher signal level before saturating. See also **Variable Gain**.

Linearity:

When photo response is linear, if the light intensity doubles, the detected signal will double in magnitude as well. Nonlinear response at medium to high intensities is usually due to amplifier problems, and at very low light levels poor charge transfer efficiency. A CCD's response is linear, once the bias is subtracted. Another definition of linearity is applied to the spectral positioning accuracy or tracking error of a spectrometer drive mechanism.

Noise:

Noise is common to all detectors. The total amount of signal that exists is less important than the ratio of signal magnitude to noise magnitude (S/N). With a high signal to noise ratio a signal peak can be discerned even though signal counts per second may be low. The noise components for CCD arrays are as follows:

Amplifier Noise: Some noise is introduced in the process of electronically amplifying and conditioning the signal read from the detector before conversion to a digital value. Part of **Readout Noise**.

Conversion Noise: During the conversion of an analog signal to a digital datapoint some electronic noise is introduced, statistical variations occur in the least significant bit of the converted data. Part of **Readout Noise**.

Dark Noise: The detector will integrate a thermally generated **Dark Current** at all times, whether light is reaching the detector or not. Most of the dark current signal is a steady state level that can be subtracted, and so will not ultimately contribute to the noise. However, a component of **Dark Current** is **Dark Noise** due to statistical variations in the Dark Current. The Dark Noise component increases as the square root of the Dark Current. Dark Current, and therefore Dark Noise, can be reduced by cooling. The LN_2 cooled CCD is one of the

least noisy detectors available, with less than one electron/pixel/hour of dark signal. If the signal level is below saturation, increasing the signal integration time per readout will minimize the effect that dark noise has on the acquired signal. If the signal level is too high, summing multiple reads can give similar improvement. (See **Readout Noise** below.)

Readout Noise: The electronic noise impressed on the signal during the readout and digitizing of the signal. For convenience, usually all of the noise associated with resetting, amplifying, and converting the signal are considered as readout noise. When averaging signal by acquiring over a long interval of time, increasing the signal integration time per readout rather than summing multiple readouts is preferred. This will proportionately reduce the readout noise component in the acquired signal. However, the integration time must be short enough to prevent saturation of any individual pixels and to keep the digital signal for any datapoint below the ADC limit.

Reset Noise: Following pixel or bin readout, the readout register is reset to a level approaching zero charge. **Reset Noise** is the non-uniformity in the resetting. This is canceled by **Correlated Double Sampling**. Part of **Readout Noise**.

Shot Noise: This is due to the random statistical variations of light. It includes both experimental and dark signal components. Shot noise is equal to the square root of the number of electrons generated. Its effect can be minimized by increasing signal intensity, signal integration time, or summing a number of readouts.

Photoelectric Effect:

Some materials respond to illumination from photons by releasing electrons. When light of sufficient energy hits a photosensitive material, an electron is freed from being bound to a specific atom. Such materials include the P-N junctions of the silicon photodiodes used in CCD arrays. The energy of the light must be greater than or equal to the binding energy of the electron to free an electron. The shorter the wavelength, the higher the energy the light has.

Photoelectron

A photoelectron is an electron that is released through the interaction of a photon with the active element of a detector. The photoelectron could be released either from a junction to the conduction band of a solid state detector, or from the photocathode to the vacuum in a PMT. A photoelectron is indistinguishable from other electrons in any electrical circuit.

Photo Response NonUniformity (PRNU)

PRNU is the peak to peak difference in response between the most and least sensitive elements of an array detector, under a uniform exposure giving an output level of $V_{Sat}/2$. These differences are primarily caused by variations in doping and silicon thickness.

Quantum Efficiency (QE):

The efficiency of the photoelectric effect of a detector can be quantified. The quantum efficiency of a detector is the ratio of number of photoelectrons produced to the number of photons impinging on a photoactive surface. A QE of 20% would indicate that one photon in five would produce a distinguishable photoelectron. CCD's are made of silicon which has a high QE, about 45-50% at its peak at 750 nm. The quantum efficiency of a detector is determined by several factors. These include the material's intrinsic electron binding energy or band gap, the reflectivity of the surface, the thickness of the surface, and energy of the impinging photon (h). The QE varies with the wavelength of incident light. Standard CCD's typically have a peak QE of about 50%. Back thinned CCD's may peak at about 85%. The QE at short wavelengths can be improved by coating with fluorescent dye that converts UV light to longer wavelengths where the quantum efficiency of the chip is higher. The graphs on page 14 show the QE of several available CCD's.

Readout Time:

The **Readout Time** of a CCD is the interval required to move the charges from their locations in the array to the readout registers, sample the charges, amplify them and convert them to datapoints. A consideration with a CCD is that the time between sample exposures can be longer than linear array detectors. This is because the readout requires that the charges be moved across the array (charge coupled). Also, the correlated double sampling readout technique requires more time per pixel.

Responsivity

Responsivity is the ratio of output voltage to corresponding exposure ($\mu J/cm^2$). Technically it is measured at $V_{Sat\ min}/2$ under specified conditions of illumination, readout rate, and temperature.

Saturation Level

The maximum signal level that can be accommodated by a device is its saturation level. At this point, further increase in input signal do not result in a corresponding increase in output. This term is often used to describe the upper limit of a detector element, an amplifier, or an ADC.

Spectral Response:

Most detectors will respond with higher sensitivity to some wavelengths than to others. The spectral response of a detector is often expressed graphically in a plot of responsivity versus wavelength.

UV Overcoating (Enhancement):

Although silicon junctions release photoelectrons when illuminated with UV light, the depth of penetration into the silicon is very shallow. With this shallow penetration, the probability of a UV photon penetrating to the depletion zone is less than for longer wavelength photons. Thus the QE is lower in the UV than in the visible and NIR. By coating the chip with a fluorescent dye that converts UV light to longer wavelengths, the probability of photon detection is increased. This is because the longer wavelength photons emitted by the excited dye are able to penetrate to the depletion layer of the CCD.

Variable Gain:

If a CCD has a quantum efficiency of 50%, then with two incident photons, a chip would produce one electron. With an electronic signal gain that produces one ADC count per electron, the system can measure that single electron, or two photons. If one ADC count equates to four electrons, then eight photons would be needed to produce those four measurable electrons, and thus one count. With a higher gain, one e-/count, the ability to resolve weak signals close to the noise level is increased. This is extremely important in applications such as Raman, where signals are typically very weak. By increasing the gain to measure signal levels which are very close to the noise, one can improve the signal to noise ratio while maintaining the same integration time. Or, one can achieve the same signal to noise ratio in less time.

A low gain has its applications as well. It is useful for preserving the full dynamic range of the CCD chip when measuring more intense signal levels. With a 16 bit ADC and one count equaling one electron, the ADC can only count a total of 65,000 electrons (with QE=50%, 130,000 photons). When the one ADC count equals four electrons, the 16 bit ADC counts to a maximum of 4 x 65,000 or about 250,000 electrons (500,000 photons) which is close to the full well capacity of the chip.

Variable Gain is needed to allow optimization between maximum sensitivity and full chip dynamic range. It allows trading off the ability to distinguish a small signal from noise in order to increase the highest signal level measurable, or vice versa.

APPENDIX B: AC POWER SELECTION AND FUSING

The power input module combines the line voltage selection, fuse holder, on / off switch and power line cord entry into one compact unit. To change the main power fuse, disconnect the line cord and pry the cover open. The fuse will come out in a cartridge with the cover. Printed on the cover are voltage ranges followed by a small arrow. The fuse for that voltage range is located on the same side of the cartridge as the arrow. Once the fuse is replaced, insert the cartridge so that the arrow next to the voltage range being used lines up with the small white dash on the controller.

Circuit	Line Voltage	Fuse rating (3AG type)
Input Power	100 VAC	2 Amp slow blow
	120 VAC	2 Amp slow blow
	220 VAC	1 Amp slow blow
	240 VAC	1 Amp slow blow
Shutter Fuse	N/A	1 Amp fast blow

APPENDIX C: PC COMMUNICATIONS CARD ADDRESS, IRQ, AND DMA JUMPERS

Normally, the default jumper settings from the factory will allow use of the PC interface card without conflict. If problems are encountered, the jumper settings required to change the DMA channel, the Address, and IRQ setting are shown below.

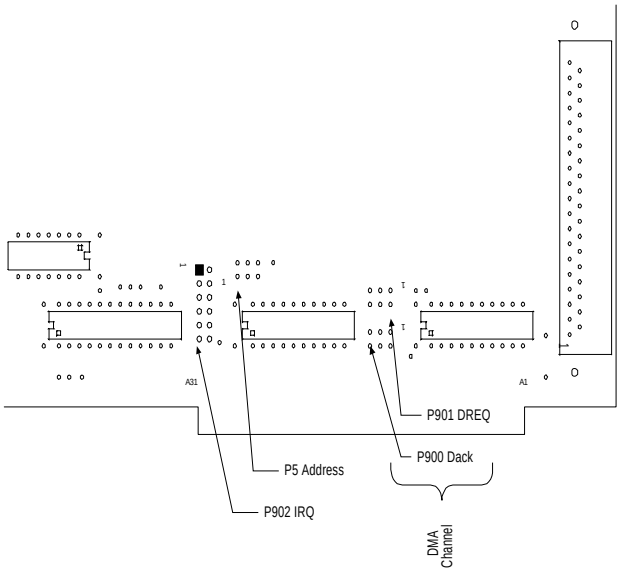


Figure 18: PC Interface Jumper Locations

P902 IRQ Selection (Default: 5)	
IRQ	Jumpered Pins
2	11 to 12
3	9 to 10
4	7 to 8
5	5 to 6
6	3 to 4
7	1 to 2

P5 Controller board Address Selection (Default: E20)			
Address	Pins 1-2	Pins 3-4	Pins 5-6
INVALID	Short	Short	Short
220	Short	Short	Open
620	Short	Open	Short
A20	Short	Open	Open
E20	Open	Short	Short
1220	Open	Short	Open
1620	Open	Open	Short
1A20	Open	Open	Open

DMA Channel Selection (Default: 1)		
DMA Channel	DREQ Jumper P901	DACK Jumper P900
DMA1	5 to 6	5 to 6
DMA2	3 to 4	3 to 4
DMA3	1 to 2	1 to 2

APPENDIX D: INTERFACE DRAWINGS:

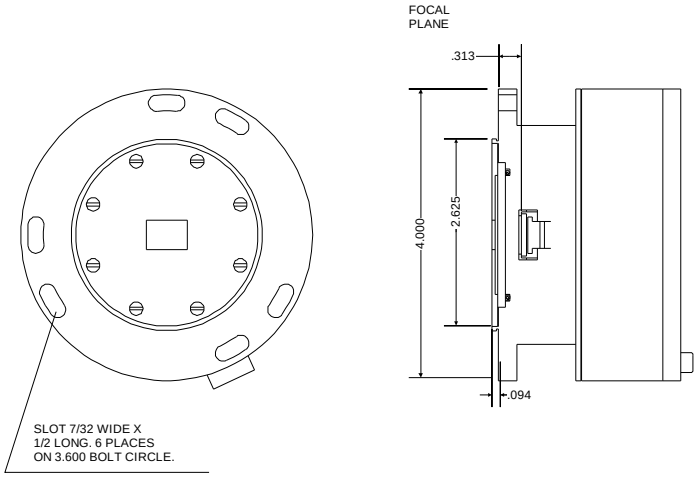


Figure 19: LN2 Head Mounting Flange

MAN0099

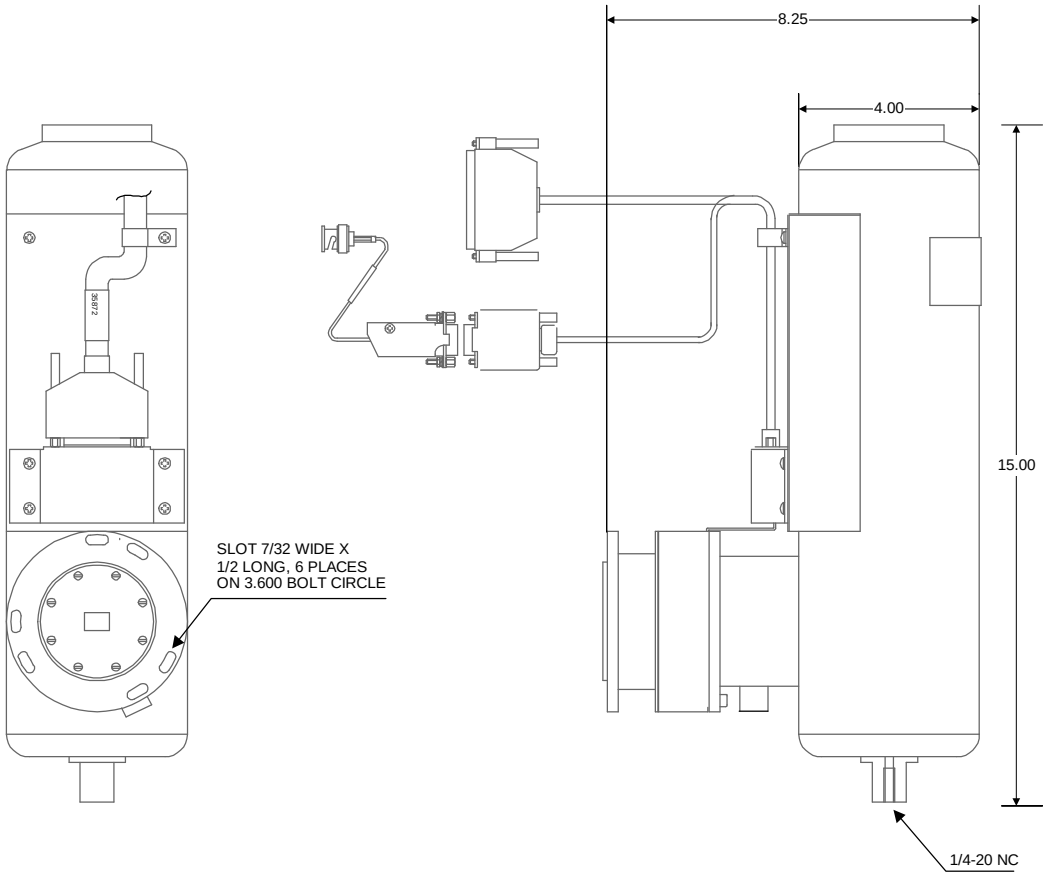


Figure 20: 1 Liter Side Mount LN_2 Dewar

MAN0090

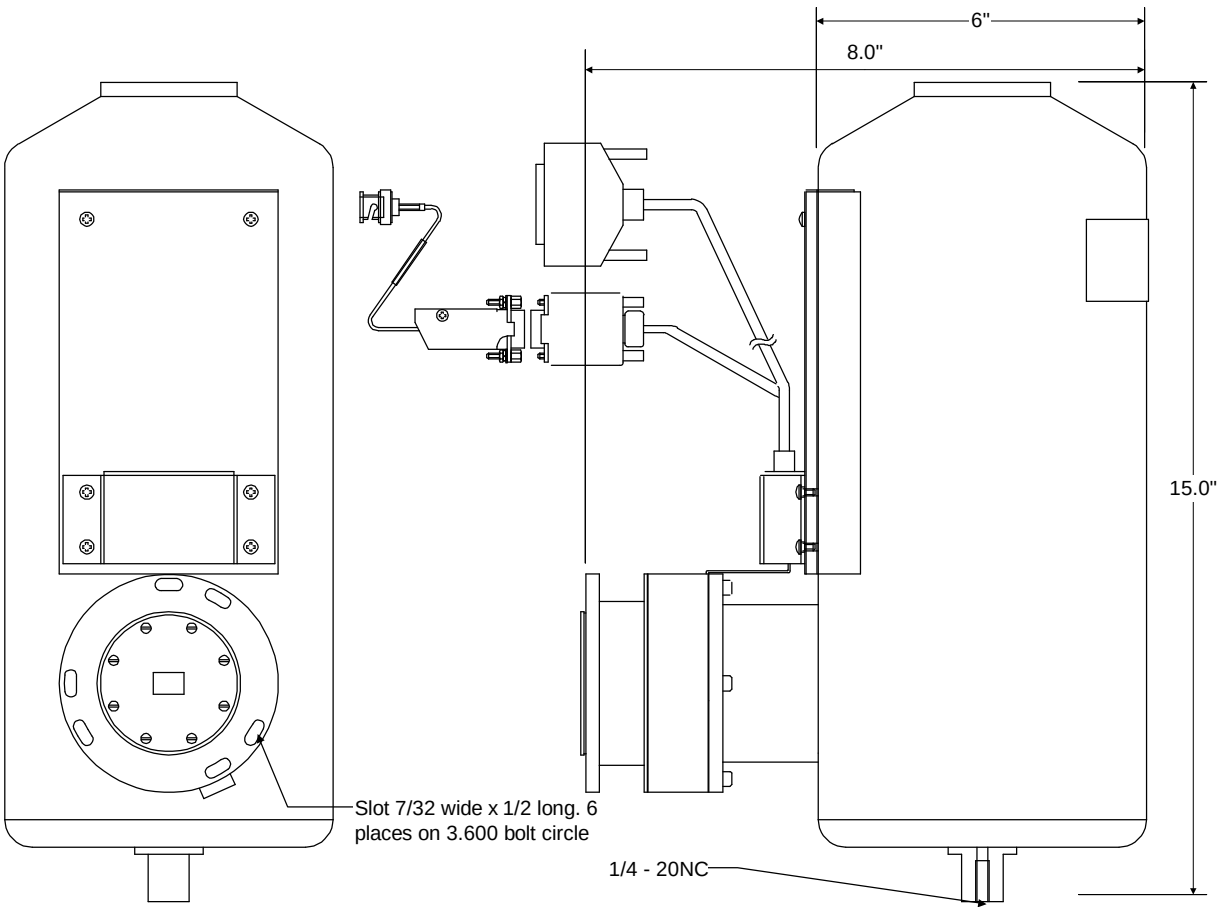


Figure 21: 2.8 Liter Side - Looking LN_2 Dewar

MAN0111

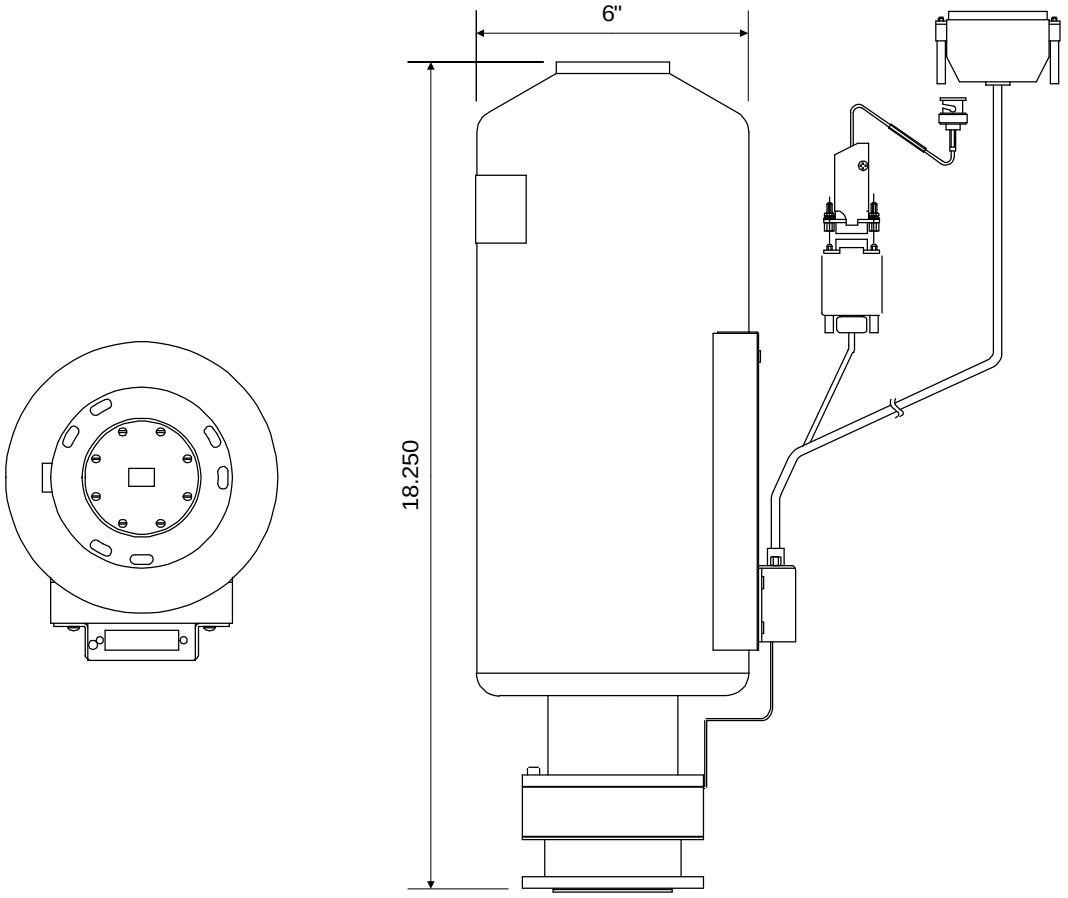


Figure 22: 2.8 Liter Down - Looking LN_2 Dewar

MAN0092

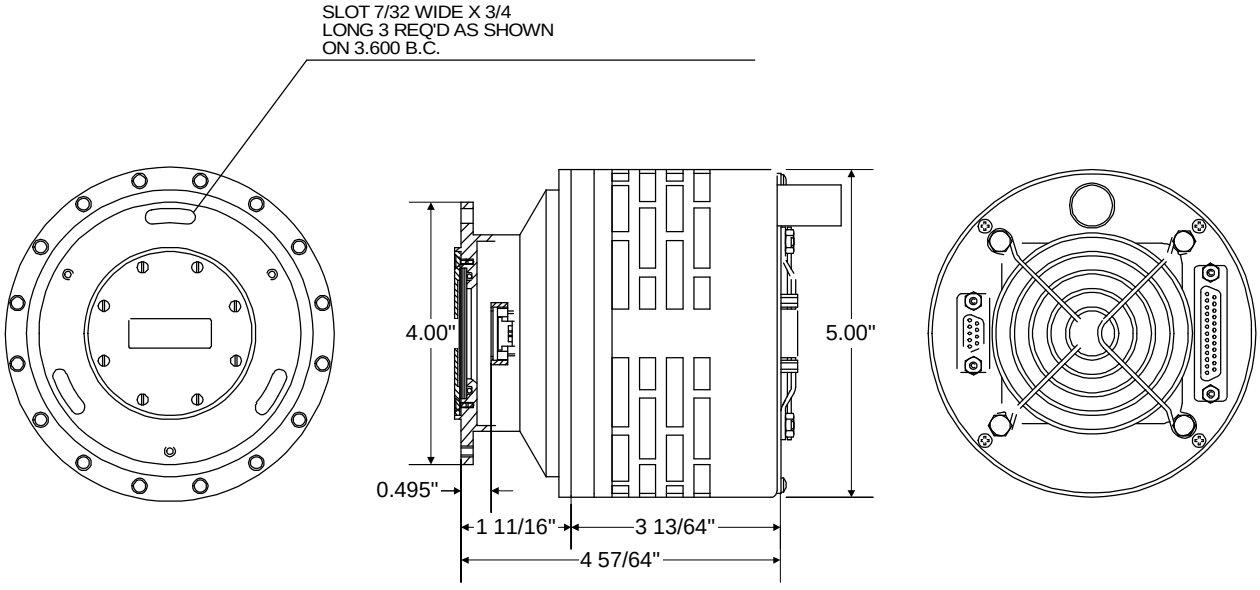


Figure 23: Air Cooled TE CCD Head

MAN0088

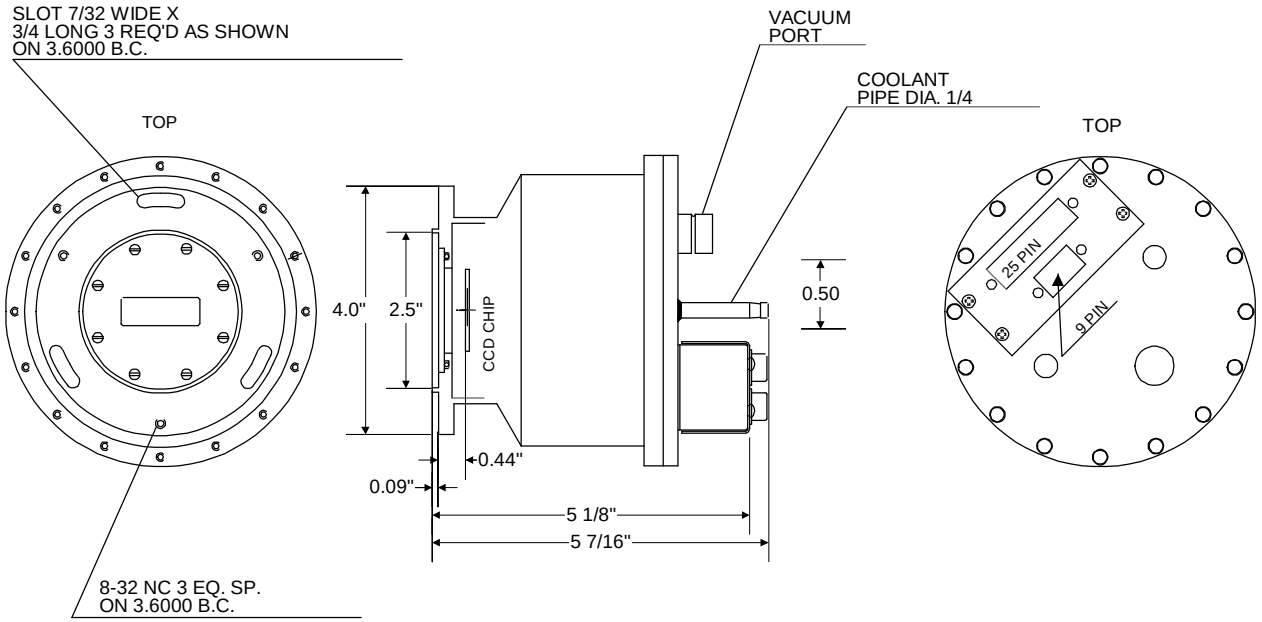


Figure 24: Water Cooled TE CCD Head

MAN0086

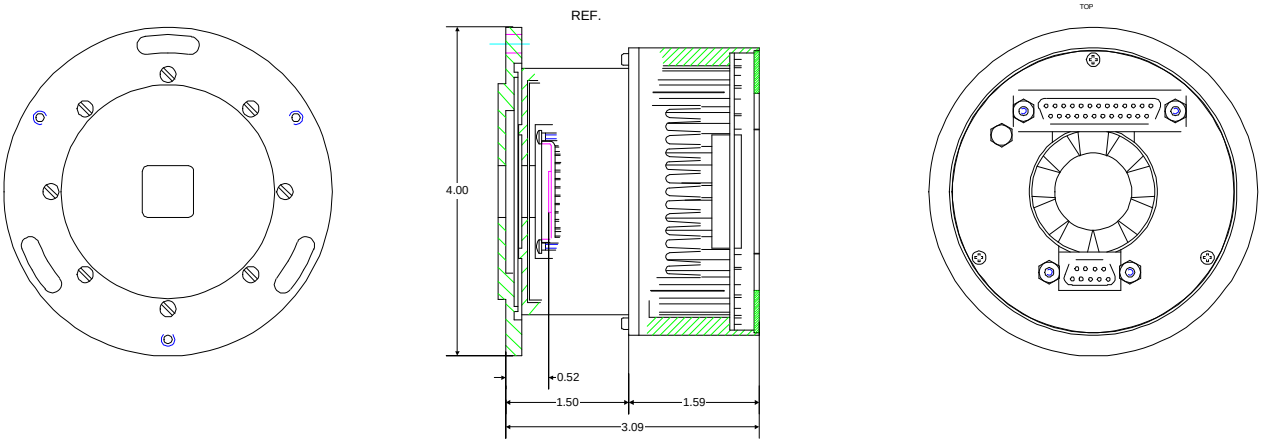


Figure 25: Mini-TECCD interface

MAN0110

APPENDIX E: CCDLOAD.EXE SOFTWARE DRIVER

The Charge Coupled Device (CCD) detection system is provided with SpectraMax general purpose commercial software. For those cases where a more compact software or more specific functionality may be required, a software driver is provided to facilitate communication with the controller boards. With this driver, an experienced programmer will be able to write routines to control the CCD and acquire data with it.

The Spectrum One CCD detection system is compatible with the IBM PC/AT bus. The RISC interface card plugs into a slot in the host PC. The software, including the CCD driver are loaded from a floppy diskette. Refer to the SpectraMax Software Manual shipped with the system for installation instructions.

This section of the manual outlines the driver calls that are available to controlling programs. The CCDLOAD.EXE driver is a low level interface to software that user-programmers may create. This driver is used by and included with SpectraMax software. Writing programs utilizing device drivers such as CCDLOAD.EXE requires considerable programming skill, and is therefore not recommended for the occasional or novice programmer. Teaching the skill of programming is beyond the scope of this document.

To avoid confusion, it is best to be sure that the hardware is installed properly and that the system is functioning normally first, then proceed to writing, testing, and debugging a new program. Please complete the hardware and software installation and check out the system with SpectraMax before trying the new program.

This manual covers the usage and protocol for the CCDLOAD.EXE driver calls. The calls will directly control the CCD and associated accessories.

Note that spectrometer movements can be interfaced via a JY232/488 or SPEX232/488 control interface, not via CCDLOAD or CCD2000 controller.

Contents of CCDLOAD Appendix:

System Hardware Requirements for CCDLOAD.EXE:

To support the CCDLOAD .EXE driver, the following hardware is required:

IBM compatible PC/ AT with a minimum of 64K conventional memory,
a Hard disk drive, and a floppy drive to load the program

The PC bus speed must be 8 MHz

1½ full length, full height PC/ AT expansion card slot is required to mount the RISC interface boards

A math coprocessor is not required

The Driver has been tested on systems up to a Pentium 90Mhz.

Installation:

This section assumes that the CCD hardware and SpectraMax software installation and checkout have been completed successfully. On that basis, one can proceed with confidence in the proper functioning of the detector electronics.

In order to use the CCD Driver, first it must be loaded. This is accomplished by typing CCDLOAD at the DOS prompt. All the parameters are optional, any or all of them can be omitted. The sequence and case are unimportant.

Syntax is as follows:

ccdload [/ppath] [/e] [/?] [/{i|f|h}nnn] [/u] [/d3]

Where:

/p	this is the DOS path to the initialization files
/e	turns on the emulate hardware mode, the CCD controller need not be connected
/?	shows syntax requirements, echoed to the screen
/f	nnn is the software interrupt to be used, disregarding any conflict with others already in use.
/i	nnn is the software interrupt to be used, but if conflicting with previous interrupt assignment, driver will not load
/u	unloads previously loaded copy of CCDLOAD, restoring memory to the system. If the driver was loaded with a specified interrupt vector be sure to unload using the same interrupt vector. If any other Terminate and Stay Resident (TSR) programs are loaded after CCDLOAD, the driver program will not unload itself.

/d sets the DMA channel; default is 1, if necessary use the /d3 switch to set to channel 3 only
/h nnn sets the hardware interrupt

The driver hooks the DOS equipment list when loaded and the driver interrupt used can be obtained from a call to is_driver_loaded (int service_id) as defined on page in the code example section.

Upon loading, the driver reads the following files which must be in the current directory:

List of Files:

File:	**Contains:**
CCDLOAD.INI	Chip & controller specific information
CCD.INB	Voltage settings
FLUSH32.D	RISC code file
CSETTEMP.D	RISC code file
CTEMPS.D	RISC code file
SHUT32.D	RISC code file
C578COL.D	RISC code file
CSHUTTER.D	RISC code file
OSHUTTER.D	RISC code file

NOTE: If the batch file HWINIT.BAT is used from time to time to optimize the chip, unload and then re-load the driver so that it reads the updated information.

Summary of CCD Driver Calls:

(Decimal) #	Function Name	Use
0	DRV_INITIALIZE	Initialize the Driver
1	DRV_TIMEOUT	set a t/o for comm. init
2	HW_INITIALIZE	force init and set flag
3	READ_HW_INIT_STATUS	check if init flag is set
4	INITIALIZE_BUSY	check if received confirm after init
300	CCD_INIT	Initialize CCD hardware
301	CCD_SET_EXPOSURE_TIME	Sets the exposure time
302	CCD_SET_GAIN	Set the gain
303	CCD_READ_GAIN	Returns the current gain setting
304	CCD_SET_AREAS	Sets acq format, areas, data pointers, returns size of acquisition buffer(s) needed
305	CCD_SET_NUMBER_OF_FLUSHS	Sets the number of flushes
306	CCD_SET_DOUBLE_COR_TIME	Sets the double correlation time
307	CCD_SET_TEMPERATURE	Sets the CCD temperature
308	CCD_READ_TEMPERATURE	Returns the current CCD temperature
310	CCD_READ_CHIP_STUFF	Returns CCD chip specific info
311	CCD_GO	Starts an acquisition
314	CCD_STOP	Stops any CCD operation in process
322	CCD_GO_BLANK	Starts a blank acquisition (shutter closed)
312	CCD_BUSY	Tests if acquisition is busy

315	CCD_READ_IMAGE	Transfers next serial row of image data
316	CCD_READ_SCAN	Transfers scan area data
317	CCD_RESET_IMAGE	Sets image transfer back to 1st serial row
318	CCD_RESET_SCAN	Sets area transfer back to 1st area
319	CCD_READ_NEXT_SCAN	Transfers next area of scan data
320	CCD_OPEN_SHUTTER	Opens the CCD shutter
321	CCD_CLOSE_SHUTTER	Closes the CCD shutter
190	COMMUTATION_INIT	Initialize a commutation device
191	COMMUTATION_SETUP	Setup up for a commutation movement
192	COMMUTATION_GO	Move the commutation device
195	COMMUTATION_STATUS	Determine the status of a commutation device

Microsoft C Example Call to the CCD Driver:

Note: The following macros are defined by Microsoft C in the DOS.H file:

FP_SEG, FP_OFF, REGS, and SREGS. in Microsoft C version 5.1. This is the version used in this example.

For version 7., Microsoft changed the definitions to _FP_SEG, _FP_OFF, _REGS, and _SREGS

To prevent errors in compiling, make these changes.

To make an interrupt call in other programming languages or other versions of C , See the documentation provided with the language or version in use.

```
#define CCD_DRIVER      0xA2

Global
int  driver_interrupt;

     driver_interrupt = is_driver_loaded( CCD_DRIVER );

/* interrupt at which CCDLOAD is hooked to */
/* This was either specified on command line when CCDLOAD was loaded
   or was determined at load time to be the first free interrupt found.
*/


#include <dos.h>

int is_driver_loaded( int service_id )
{
union REGS intregs;
struct SREGS intsregs;

   intregs.h.ah = (unsigned char)service_id;
   intregs.x.bx = 0;

   (void) int86x( 0x11, &intregs, &intregs, &intsregs);

   return( intregs.x.bx );

}

//-------------------------------------------------------------------------
void far *ccddriver( word command , void *param_ptr )
{
/* uses global driver_interrupt */

void far        *result_ptr;
unsigned        tseg,
                toff;
```

```
union REGS      intregs;
struct SREGS    intsregs;

/* obtain segment and offset of parameter block */
   tseg = FP_SEG( param_ptr );
   toff = FP_OFF( param_ptr );

/* pass segment and pointer in ds and dx */
   intsregs.ds  = tseg;
   intregs.x.dx = toff;

/* command is passed in ax */
   intregs.x.ax = command;

   (void) int86x(driver_interrupt, &intregs, &intregs, &intsregs);

/* ax is non-zero if an error occurred in the driver */
   if ( intregs.x.ax )
      {
      /* Error routine goes here */
      /* See (Appendix A) for possible error codes */
      }

/* ds and dx contain the segment and offset of the result pointer */
   tseg = intsregs.ds;
   toff = intregs.x.dx;

/* make a pointer for the return */
   result_ptr = MK_FP( tseg , toff );

   return( result_ptr );
}
```

Microsoft C Examples of Function Calls:

```
//-------------------------------------------------------------------
Function:       DRV_INITIALIZE                  0

Example:

typedef struct
         {
         char  version[16];            /* driver version */
         char  id[16];                 /* driver id      */
         } driver_parms;

driver_parms    *drvparms;

   drvparms = ( driver_parms *) ccddriver( DRV_INITIALIZE, NULL );
```

Explanation:

This function initializes the driver, and returns the driver version and driver id, it must be called prior to any other driver calls to verify the version.

```
//-------------------------------------------------------------------
Function:  CCD_INIT                         300

Example:

byte ccd_number = 1;
int ccd_hardware;

        ccd_hardware = *( int *) ccddriver( CCD_INIT, &ccd_number );
```

Explanation:

Initializes CCD hardware; returns TRUE if hardware is present FALSE otherwise. If hardware is not detected the driver will perform hardware emulation as much as possible which is very useful for software testing.

```
//-------------------------------------------------------------------
Function:  CCD_SET_EXPOSURE_TIME          301

Example:

byte_long     ccd_pass;

   ccd_pass.byte0 = 1;       /* ccd number */
   ccd_pass.long0 = 1000L;   /* time in milliseconds */

   ( void ) ccddriver( DRV_SET_EXPOSURE_TIME, &ccd_pass );
```

Explanation:

This function sets the time in milliseconds which will be used for all subsequent acquisitions.

```
//-------------------------------------------------------------------------
Function:  CCD_SET_GAIN                  302

Example:

byte_word     ccd_pass;

   ccd_pass.byte0 = 1;       /* ccd number */
   ccd_pass.word0 = 1;       /* gain */

   ( void ) ccddriver( CCD_SET_GAIN , &ccd_pass );

Explanation:

  Sets the CCD gain.


//-------------------------------------------------------------------------
Function:  CCD_READ_GAIN                 303

Example:
byte ccd_number = 1;
int     gain;

        gain = *(int *) ccddriver( CCD_READ_GAIN, &ccd_number );

Explanation:

   Returns the current gain setting.


//-------------------------------------------------------------------------
Function:  CCD_SET_AREAS                 304

Example:

int acq_size;

ccd_user_struct ccd_user_data;

    acq_size = *(int *) ccddriver( CCD_SET_AREAS, &ccd_user_data );


Explanation:

   Provides pointers to user data areas. "ccd_user_data" must always be
available after this call. User data buffer(s) must be at least "acq_size"
integers in length.

NOTE: CCD_SET_AREAS sets "my_areas[0...number_of_areas].data_ptr" to NULL The
program must now assign them to point to the data spaces allocated.

See "ccd_user_struct" for details.
```

```
//-------------------------------------------------------------------------
Function:  CCD_SET_NUMBER_OF_FLUSHS       305

Example:

byte_word     ccd_pass;

   ccd_pass.byte0 = 1;       /* ccd number */
   ccd_pass.word0 = 1;       /* number of flushs */

   ( void ) ccddriver( CCD_SET_NUMBER_OF_FLUSHS, &ccd_pass );

Explanation:

  Sets the number of flushes of the CCD which will occur prior to starting an
acquisition.


//-------------------------------------------------------------------------
Function:  CCD_SET_DOUBLE_COR_TIME        306

Example:

byte_word     ccd_pass;

   ccd_pass.byte0 = 1;       /* ccd number */
   ccd_pass.word0 = 23;      /* double correlation time */

   ( void ) ccddriver( CCD_SET_DOUBLE_COR_TIME, &ccd_pass );

Explanation:

  Resets the double correlation time. The units are clock cycles = 1/6
microsecond. See CCD user manual for details.


//-------------------------------------------------------------------------
Function:  CCD_SET_TEMPERATURE            307

Example:

byte_word     ccd_pass;

   ccd_pass.byte0 = 1;       /* ccd number */
   ccd_pass.long0 = 0;       /* temperature in deg K */

   ( void ) ccddriver( CCD_SET_TEMPERATURE, &ccd_pass );

Explanation:

   Sets the CCD to the temperature requested in degrees K. Use
CCD_READ_TEMPERATURE to determine stability; this typicaly takes 20 minutes.
NOTE: Reinitialize with HWINIT.BAT after a temperature change. This implies
that the driver should be unloaded and reloaded to read new HWINIT parameters
written to CCD.INB.
```

```
//-------------------------------------------------------------------------
Function:  CCD_READ_TEMPERATURE          308

Example:

byte ccd_number = 1;
int             temperature_1;

   temperature_1 = *(long *) ccddriver( CCD_READ_TEMPERATURE, &ccd_number
);

Explanation:

   Returns the CCD head temperature in degrees K.


//-------------------------------------------------------------------------
Function:  CCD_READ_CHIP_STUFF           310

Example:

ccd_tsr_struct chip_data;

  chip_data.ccd_number = 1;
  ( void )ccddriver( CCD_READ_CHIP_STUFF,&chip_data );

Explanation:

   Returns hardware specific information.

See "ccd_tsr_struct" starting on page  for details.


//-------------------------------------------------------------------------
Function:  CCD_GO                        311

Example:

byte ccd_number = 1;

   ( void ) ccddriver( CCD_GO, &ccd_number );
Explanation:

    Starts the data acquisition sequence of:
       close shutter,
       perform number_of_flushes
       start integration - open shutter,integrate, close shutter
       transfer data from chip to RISC memory

NOTE: The actual execution of this sequence relies on calls to CCD_BUSY;


//-------------------------------------------------------------------------
Function:  CCD_STOP                        314

Example:

byte ccd_number = 1;

   ( void ) ccddriver( CCD_STOP, &ccd_number );
```

```
Explanation:

    Stops any CCD operation in process


//-------------------------------------------------------------------------
Function:  CCD_GO_BLANK                    322

Example:

byte ccd_number = 1;

   ( void ) ccddriver( CCD_GO_BLANK, &ccd_number );

Explanation:

    Starts the data acquisition sequence of:
       close shutter
       perform number_of_flushes
       start integration - integrate (Shutter is NOT opened)
       transfer data from chip to RISC memory

NOTE: The actual execution of this sequence relies on calls to CCD_BUSY;


//-------------------------------------------------------------------------
Function:  CCD_BUSY                        312

Example:

byte ccd_number = 1;
int     busy;

    busy = *(int *) ccddriver( CCD_BUSY, &ccd_number );

Explanation:
  Steps the CCD_GO sequence to the next state. Returns busy = next_state ( !=
0 ) until done ( == 0 ).


//-------------------------------------------------------------------------
Function:  CCD_READ_IMAGE                  315

Example:

byte ccd_number = 1;
    ( void ) ccddriver( CCD_READ_IMAGE, &ccd_number );

Explanation:

  Transfers  1  serial  row  of  data  into  the  storage  area  specified  in
"ccd_user_data". See CCD_SET_AREAS for details.

The program must perform multiple calls to this function until the entire
image is transfered.
```

```
//-------------------------------------------------------------------------
Function:  CCD_READ_SCAN                  316

Example:

byte_word area_number;

area_number.byte0 = 1; /* CCD number */
area_number.word0 = -1; /* area number of -1 = read ALL areas */

   ( void ) ccddriver( CCD_READ_SCAN, &area_number );

Explanation:

  Transfers data for "area_number" into user allocated storage specified in
"ccd_user_data". If area_number = -1, ALL scan data will be transfered.

NOTE: This function can be randomly addressed by "area_number" but speed may
be sacrificed.

NOTE: Transfer fastest if all of the storage is allocated at once and read ALL
areas.

See CCD_SET_AREAS for details.


//-------------------------------------------------------------------------
Function:  CCD_RESET_IMAGE                317

Example:

byte ccd_number = 1;
   ( void ) ccddriver( CCD_RESET_IMAGE, &ccd_number );

Explanation:

   Resets internal memory pointers so that the next call to CCD_READ_IMAGE
will start at the begining of the image. This is useful for multiple reads of
the data from RISC memory for display purposes etc.


//-------------------------------------------------------------------------
Function:  CCD_RESET_SCAN                 318

Example:

byte ccd_number = 1;
   ( void ) ccddriver( CCD_RESET_SCAN, &ccd_number );

Explanation:

   Resets internal memory pointers so that the next call to CCD_READ_SCAN will
start at the beginning of the 1st area. This is useful for multiple reads of
the data from RISC memory for display purposes etc.
```

```
//-------------------------------------------------------------------------
Function:  CCD_READ_NEXT_SCAN            319

Example:

byte ccd_number = 1;
   ( void ) ccddriver( CCD_READ_NEXT_SCAN, &ccd_number );
```

Explanation:

Transfers data sequentialy from the next area into user allocated storage specified in "ccd_user_data".

NOTE: This function returns data areas in sequence. The program must call CCD_RESET_SCAN first to initialize the internal area counter.

NOTE: This method of data transfer is slower than if ALL areas are read at once (see CCD_READ_SCAN with area number = -1), but may be faster than calling CCD_READ_SCAN for 1 area at a time. The speed will depend upon the CCD chips physical read out register direction.

See CCD_SET_AREAS for details.

```
//-------------------------------------------------------------------------
Function:  CCD_OPEN_SHUTTER              320

Example:

byte ccd_number = 1;
   ( void ) ccddriver( CCD_OPEN_SHUTTER, &ccd_number );
```

Explanation:

Opens the CCD shutter.

```
//-------------------------------------------------------------------------
Function:  CCD_CLOSE_SHUTTER             321

Example:

byte ccd_number = 1;
   ( void ) ccddriver( CCD_CLOSE_SHUTTER, &ccd_number );
```

Explanation:

Closes the CCD shutter.

Commutations are a JY generalization of the OPEN/CLOSE shutter commands. If the programmer has experience programming with other JY/ISA/SPEX drivers they are the same with the CCD shutter being commutation number 1; if the programmer is not familiar with this convention these calls may be ignored.

```
//-------------------------------------------------------------------------
Function:       COMMUTATION_INIT                190

Example:

   (void) ccddriver( COMMUTATION_INIT, NULL );

Explanation:

    This function initializes the shutter driver calls.


//-------------------------------------------------------------------------

Function:       COMMUTATION_SETUP               191

Example:

typedef struct
         {
         byte  byte0;
         word  word0;
         word  word1;
         word  word2;
         word  word3;
         word  word4;
         } byte_multi_word;

byte_multi_word shutter_parms;

   shutter_parms.byte0 = 1;        /* Must always be 1 */
   shutter_parms.word0 = SHUTTER;  /* Type */
   shutter_parms.word1 = 2;        /* Number of possible states */

   shutter_parms.word2 = SHUTTER_CLOSED;        /* Requested State */
   shutter_parms.word3 = 0;                     /* NOT_USED */
   shutter_parms.word4 = 0;                     /* NOT_USED */
   (void) ccddriver( COMMUTATION_SETUP, &shutter_parms );

Explanation:

    This function sets the parameters for next COMMUTATION_GO command to this
device.   The first 3 parameters must always be 1, 1, and 2, the fourth
parameter is either 1 or 0 depending on whether it is necessary to open or
close the shutter.


//-------------------------------------------------------------------------
Function:       COMMUTATION_GO                  192

Example:

byte  shutter_num;

   shutter_num = 1;                             /* Must always be 1 */
   (void) ccddriver( COMMUTATION_GO, &shutter );

Explanation:
```

This function moves the shutter to the position specified by a previously executed COMMUTATION_SETUP command.

```
//-------------------------------------------------------------------------
Function:       COMMUTATION_STATUS              195

Example:

byte_multi_word shutter_status;
unsigned char   shutter_num;

   shutter_num = 1;                             /* Must always be 1 */
   shutter_status = ccddriver( COMMUTATION_STATUS, &shutter_num );

Explanation:
```

This function returns the current state of the shutter in the structure shutter_status.

Definitions of Numbered Codes:

Setup and Communications Error Codes

NO_PROBLEM	0
HARDWARE_PROBLEM	1
FUNCTION_NOT_AVAILABLE	2
PARAMETER_PROBLEM	3
NOT_INITIALIZED	4
RECEIVE_ERROR	5
TRANSMIT_ERROR	6
BAD_CONFIRMATION	7
UNKNOWN_CONFIRMATION_ERROR	8
FRAMING_ERROR	9
PARITY_ERROR	10
OVERRUN_ERROR	11
COM_PORT_ERROR	12
BAUD_RATE_ERROR	13
COM_PARAM_ERROR	14
RCV_TIME_OUT_ERROR	15

CCD Low Level Error Codes:

CCD_OK	NO_PROBLEM
CCD_NULL_USER_POINTER	20
CCD_NOT_ENOUGH_MEMORY	21
CCD_ALTPARAM	22
CCD_LOAD	23
CCD_READPROG	24
CCD_TIMEOUT	25
CCD_ZEROLOOP	26

Commutation Devices:

SHUTTER_CCD	1

Commutation Types:

SHUTTER_TYPE	1

Commutation States:

SHUTTER_OPEN	1
SHUTTER_CLOSED	0

Commutation (Shutter) Function Numbers:

COMMUTATION_INIT	190
COMMUTATION_SETUP	191
COMMUTATION_GO	192
COMMUTATION_STATUS	195

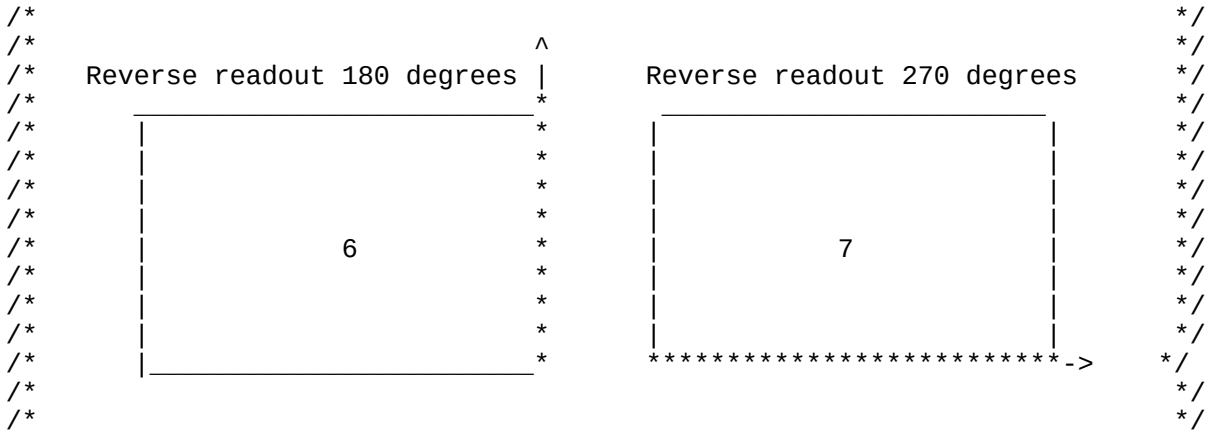
Acquisition Formats:

Image_format	0
Region_format	1

Type Definitions:

```
#pragma pack(1)

typedef unsigned char   byte;
typedef unsigned int    word;

typedef struct
   {
   char  version[16];        /* driver version  */
   char  id[16];             /* driver id       */
   }  driver_parms;

typedef struct
   {
   byte  byte0;
   byte  byte1;
   } byte_byte;

typedef struct
   {
   byte  byte0;
   word  word0;
   } byte_word;

typedef struct
   {
   byte  byte0;
   long  long0;
   } byte_long;

/*__For JY Commutations ____________________________________________________*/

typedef struct
   {
   byte  byte0;
   word  word0;
   word  word1;
   word  word2;
   word  word3;
   word  word4;
   } byte_multi_word;
/*_____________________________________________________________________________*/

typedef struct
   {
/* read from file: ccdload.ini */
   byte           ccd_number;

   int            port;

   int            total_active_x_pixels;
   int            total_active_y_pixels;

   int            num_serial_pxls_before_active;
   int            num_serial_pxls_after_active;
   int            num_parallel_rows_before_active;
```

```
   int            num_parallel_rows_after_active;
   byte           register_loc_and_direction; /* 0, 90, 180, 270 degrees */
/*                                                                        */
/*         readout register location and direction                        */
/*         add one from each of the following:                            */
/*               register location =     0       left                    */
/*                                      1       top                       */
/*                                      2       right                     */
/*                                      3       bottom                    */
/*                                                                        */
/*         direction is relative to our standard configuration            */
/*         with the readout register in the left position                 */
/*               direction         =     0    clockwise                   */
/*                                       4    counter-clockwise          */
/*                                                                        */
/*                                                                        */
/*       ^                                                                */
/*       |  Std Config 0 degrees                  90 degrees              */
/*       *_____________________________          **************************->   */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *              0             |         |            1             |     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *____________________________|         |__________________________|     */
/*                                                                        */
/*                                                                        */
/*                                                                        */
/*                                                                        */
/*                 180 degrees                          270 degrees       */
/*       _____________________________*         _____________________________    */
/*       |                            *         |                          |     */
/*       |                            *         |                          |     */
/*       |                            *         |                          |     */
/*       |                            *         |                          |     */
/*       |              2             *         |            3             |     */
/*       |                            *         |                          |     */
/*       |                            *         |                          |     */
/*       |                            *         |                          |     */
/*       |____________________________*         |__________________________|     */
/*                                    |      <-**************************     */
/*                                    |                                        */
/*                                   V                                        */
/*                                                                        */
/*                                                                        */
/*        Reverse readout 0 degrees       Reverse readout 90 degrees      */
/*       _____________________________    <-**************************     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *              4             |         |            5             |     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *                            |         |                          |     */
/*       *____________________________|         |__________________________|     */
/*       |                                                                */
/*       V                                                                */
```




```
   int            min_temperature;
   int            max_temperature;

   long           min_shutter_time;
   long           max_shutter_time;

   word           min_gain;
   word           max_gain;

   int            h_pixel_spacing;
   int            v_pixel_spacing;

      /* calculated in ccd_init from above info */
   int            total_parallel_pixels; /* includes all possible pixels */
   int            total_serial_pixels;   /* includes all possible pixels */

      /* read from file: ccd.inb */
      /* may also be changed by a driver call */
   word           double_correl_integr_time;
   } ccd_tsr_struct;

/*_____________________________________________________________________________*/

typedef struct
   {
   unsigned int         *data_ptr;
   int                  x_origin,  /* offset */
                        y_origin,  /* offset */
                        size_x,    /* width  */
                        size_y,    /* heigth */
                        bin_x,
                        bin_y;
   } ccd_area_struct;

/*_____________________________________________________________________________*/

typedef struct
   {
/* passed in driver calls */
   byte           ccd_number;
   byte           acquisition_format; /* image = 0, region(scan) = 1 */
   int            number_of_areas;    /* when in region(scan) mode   */
   ccd_area_struct *area_ptr;
   } ccd_user_struct;
```

```
#pragma pack()
```

Production Code Examples:

Included on the disk is a fully functional example program written in Microsoft Quick C. This program file is : QDCCD.C. Along with it are all the files necessary to build it. This should serve as a good starting point for a new program.

```
#define CCD_REGISTER_LONG 0x01

#define  MAX_USER_AREAS  10   /* User size; not limited in driver */
/* NOTE: MAX_USER_AREAS is a user parameter; the driver allocates any
         necessary storage based on number_of_areas */

void get_ccd_data( void )
{
int   busy, row, size_x, size_y, hardware, acq_size, rows_to_read;
long  time_out, end_time;

typedef struct
         {
         char  version[16];           /* driver version */
         char  id[16];                /* driver id      */
         } driver_parms;

driver_parms    *drvparms;

byte ccd_number;
byte_long ccd_exp_time;
byte_word ccd_flushes;

ccd_tsr_struct  chip_data;

ccd_user_struct         my_data;
ccd_area_struct         my_areas[ MAX_USER_AREAS ];
word                    my_image_buff[ 2048 ];

   drvparms = ccddriver( DRV_INITIALIZE, NULL );

   ccd_number = 1;      /* CCD number; always 1 */
   hardware = *(int *)ccddriver( CCD_INIT, &ccd_number );

   chip_data = (ccd_tsr_struct *)ccddriver(CCD_READ_CHIP_STUFF,
&ccd_number);

   size_x = chip_data.total_active_x_pixels;
   size_y = chip_data.total_active_y_pixels;

   ccd_exp_time.byte0 = 1; /* CCD number; always 1 */
   ccd_exp_time.long0 = exposure_time;
   ( void ) ccddriver( CCD_SET_EXPOSURE_TIME, &ccd_exp_time );

   ccd_flushes.byte0 = 1; /* CCD number; always 1 */
   ccd_flushes.word0 = number_of_flushes;
   ( void ) ccddriver( CCD_SET_NUMBER_OF_FLUSHS, &ccd_flushes );

   my_data.ccd_number = 1;
   my_data.acquisition_format = 0;
   my_data.number_of_areas = 1;
```

```
   my_data.area_ptr = my_areas;
   my_areas[0].x_origin = 0;
   my_areas[0].y_origin = 0;
   my_areas[0].size_x = size_x;
   my_areas[0].size_y = size_y;
   my_areas[0].bin_x = 1;
   my_areas[0].bin_y = 1;

   acq_size = *(int *) ccddriver( CCD_SET_AREAS, &my_data );

/* NOTE: CCD_SET_AREAS sets "my_areas[0].data_ptr" to NULL
   must now assign it to point to the data space allocated */

   my_areas[0].data_ptr = my_image_buff;

   ( void ) ccddriver( CCD_GO, &ccd_number );

   abort = FALSE;        /* global user flag */
   time_out = 2L * exposure_time;
   end_time = time_now() + time_out; /* time_now returns current time
                                       in millseconds as a long */
   do
      {
      busy = *(int *) ccddriver( CCD_BUSY, &ccd_number );

      if ( key_board_hit() )             /* process user input */
         process_user_input();

      if ( end_time < time_now() )       /* check for time out */
         {
         display_an_error("Time Out", time_out );
         abort = TRUE;
         break;
         }
      }
   while ( busy  && !abort);       /* abort can be set by user to cancel
                                      the current acquisition */
   if ( abort )  /* user abort or time out */
      return;
   if ( chip_data.register_loc_and_direction & CCD_REGISTER_LONG )
      {
      rows_to_read = my_areas[0].size_y / my_areas[0].bin_y;
      }
   else
      {
      rows_to_read = my_areas[0].size_x / my_areas[0].bin_x;
      }
   /**  Reset image transfer back to 1st serial row **/
   ( void ) ccddriver(CCD_RESET_IMAGE, &ccd_number );
   /* Now get each row (line) of the image */
   for ( row = 0; row < rows_to_read ; row++ )
      {
        /* get a row of data */
        ( void ) ccddriver( CCD_READ_IMAGE, &ccd_number );
        /* do something with "acq_size" points of data in
           "my_image_buff" */
      }
}
//---------------------------------------------------------------------------
```

APPENDIX F: CCD3000.EXE SOFTWARE DRIVER

The Charge Coupled Device (CCD) detection system is provided with either SpectraMax general purpose commercial software. For those cases where a more compact software or more specific functionality may be required, a software driver is provided to facilitate communication with the controller boards. With this driver, an experienced programmer will be able to write routines to control the CCD and acquire data with it.

The Spectrum One CCD detection system with a CCD3000 controller is compatible with any computer using a National Instruments IEEE-488 card. The software, including the CCD driver are loaded from a floppy diskette works with an IBM PC compatible. Refer to the SpectraMax Software Manual shipped with the system for installation instructions.

This section of the manual outlines the driver calls that are available to controlling programs. The CCD3000.EXE driver is a low level interface to software that user-programmers may create. This driver is used by and included with SpectraMax software. Writing programs utilizing device drivers such as CCD3000.EXE requires considerable programming skill, and is therefore not recommended for the occasional or novice programmer. Teaching the skill of programming is beyond the scope of this document.

To avoid confusion, it is best to be sure that the hardware is installed properly and that the system is functioning normally first, then proceed to writing, testing, and debugging a new program. Please complete the hardware and software installation and check out the system with SpectraMax before trying the new program.

This manual covers the usage and protocol for the CCD3000.EXE driver calls. The calls will directly control the CCD and associated accessories.

Note that spectrometer movements can be interfaced via a JY232/488 or SPEX232/488 control interface, not via the CCD3000 controller or CCD3000.EXE.

Contents of CCD3000 Appendix:

System Hardware Requirements for CCD3000.EXE:

To support the CCD3000 .EXE driver, the following hardware is required:

IBM compatible PC/AT with a minimum of 64K conventional memory, a Hard disk drive, and a floppy drive to load the program

National Instruments IEEE-488 communications card.

A coprocessor is not required

The driver has been tested on systems up to a Pentium 90Mhz.

Installation:

This section assumes that the CCD hardware and SpectraMax software installation and checkout have been completed successfully. On that basis, one can proceed with confidence in the proper functioning of the detector electronics.

In order to use the CCD Driver, first it must be loaded. This is accomplished by typing CCD3000 at the DOS prompt. All the parameters are optional, any or all of them can be omitted. The sequence and case are unimportant.

Syntax is as follows:

```
ccd3000 [/?] [/u] [/devx] [/p] [/{i|f}nnn]
```

Where:

/?	shows syntax requirements, echoed to the screen
/p	this is the DOS path to the initialization files
/f	nnn is the software interrupt to be used, disregarding any conflict with others already in use.
/i	nnn is the software interrupt to be used (default is search for available if neither /f or /i is specified)
/dev	standard gpib device number, dev1, dev2 etc. (default dev5)
/u	unloads previously loaded copy of CCD3000, restoring memory to the system. If the driver was loaded with a specified interrupt vector be sure to unload using the same interrupt vector. If any other Terminate and Stay Resident (TSR) programs are loaded after CCD3000, the driver program will not unload itself.

The driver hooks the DOS equipment list when loaded and the driver interrupt used can be obtained from a call to is_driver_loaded (int service_id) as defined on page in the code example section.

Upon loading, the driver reads the following files which must be in the current directory:

List of Files:

File:	Contains:
CCDLOAD.INI	Chip & controller specific information
BCGAIN2.TAB	Table File
BCGAIN6.TAB	Table File
BCGAIN12.TAB	Table File
BCONVERT.TAB	Table File
ECGAIN2.TAB	Table File
ECGAIN6.TAB	Table File
ECGAIN12.TAB	Table File
ECONVERT.TAB	Table File
NIDLE.TAB	Table File
PARTRANS.TAB	Table File
SERBIN.TAB	Table File
SERCLEAR.TAB	Table File
SERWCONV.TAB	Table File
STIDLE.TAB	Table File

Summary of CCD Driver Calls:

(Decimal) #	Function Name	Use
0	DRV_INITIALIZE	Initialize the Driver
1	DRV_TIMEOUT	set a t/o for comm. init
2	HW_INITIALIZE	force init and set flag
3	READ_HW_INIT_STATUS	check if init flag is set
4	INITIALIZE_BUSY	check if received confirm after init
300	CCD_INIT	Initialize CCD hardware
301	CCD_SET_EXPOSURE_TIME	Sets the exposure time
304	CCD_SET_AREAS	Sets acq format, areas, data pointers, returns size of acquisition buffer(s) needed
307	CCD_SET_TEMPERATURE	Sets the CCD temperature
308	CCD_READ_TEMPERATURE	Returns the current CCD temperature
310	CCD_READ_CHIP_STUFF	Returns CCD chip specific info
311	CCD_GO	Starts an acquisition
314	CCD_STOP	Stops any CCD operation in process
322	CCD_GO_BLANK	Starts a blank acquisition (shutter closed)
312	CCD_BUSY	Tests if acquisition is busy
315	CCD_READ_IMAGE	Transfers next serial row of image data
316	CCD_READ_SCAN	Transfers scan area data
317	CCD_RESET_IMAGE	Sets image transfer back to 1st serial row
318	CCD_RESET_SCAN	Sets area transfer back to 1st area

319	CCD_READ_NEXT_SCAN	Transfers next area of scan data
320	CCD_OPEN_SHUTTER	Opens the CCD shutter
321	CCD_CLOSE_SHUTTER	Closes the CCD shutter
329	CCD_GO_BLAST	Set the number of acquisitions in blast mode.
190	COMMUTATION_INIT	Initialize a commutation device
191	COMMUTATION_SETUP	Setup up for a commutation movement
192	COMMUTATION_GO	Move the commutation device
195	COMMUTATION_STATUS	Determine the status of a commutation device

Microsoft C Example Call to the CCD Driver:

Note: The following macros are defined by Microsoft C in the DOS.H file:

FP_SEG, FP_OFF, REGS, and SREGS. in Microsoft C version 5.1. This is the version used in this example.

For version 7., Microsoft changed the definitions to _FP_SEG, _FP_OFF, _REGS, and _SREGS

To prevent errors in compiling, make these changes.

To make an interrupt call in other programming languages or other versions of C , See the documentation provided with the language or version in use.

```
#define CCD_DRIVER      0xA2

Global
int  driver_interrupt;

     driver_interrupt = is_driver_loaded( CCD_DRIVER );

/* interrupt at which CCDLOAD is hooked to */
/* This was either specified on command line when CCDLOAD was loaded or was
determined at load time to be the first free interrupt found. */


#include <dos.h>

int is_driver_loaded( int service_id )
{
union REGS intregs;
struct SREGS intsregs;

   intregs.h.ah = (unsigned char)service_id;
   intregs.x.bx = 0;

   (void) int86x( 0x11, &intregs, &intregs, &intsregs);

   return( intregs.x.bx );

}
//---------------------------------------------------------------------------
void far *ccddriver( word command , void *param_ptr )
{
/* uses global driver_interrupt */

void far        *result_ptr;
unsigned        tseg,
                toff;

union REGS      intregs;
struct SREGS    intsregs;
```

```
/* obtain segment and offset of parameter block */
   tseg = FP_SEG( param_ptr );
   toff = FP_OFF( param_ptr );

/* pass segment and pointer in ds and dx */
   intsregs.ds  = tseg;
   intregs.x.dx = toff;

/* command is passed in ax */
   intregs.x.ax = command;

   (void) int86x(driver_interrupt, &intregs, &intregs, &intsregs);

/* ax is non-zero if an error occurred in the driver */
   if ( intregs.x.ax )
      {
      /* Error routine goes here */
      /* See (Appendix A) for possible error codes */
      }

/* ds and dx contain the segment and offset of the result pointer */
   tseg = intsregs.ds;
   toff = intregs.x.dx;

/* make a pointer for the return */
   result_ptr = MK_FP( tseg , toff );

   return( result_ptr );
}
```

Microsoft C Examples of Function Calls:

```
//-------------------------------------------------------------------------
Function:       DRV_INITIALIZE                  0

Example:

typedef struct
         {
         char  version[16];            /* driver version */
         char  id[16];                 /* driver id      */
         } driver_parms;

driver_parms    *drvparms;

   drvparms = ( driver_parms *) ccddriver( DRV_INITIALIZE, NULL );
```

Explanation:

This function initializes the driver, and returns the driver version and driver id, it must be called prior to any other driver calls to verify the version.

```
//-----------------------------------------------------------
Function:  CCD_INIT                         300

Example:

byte ccd_number = 1;
int ccd_hardware;

        ccd_hardware = *( int *) ccddriver( CCD_INIT, &ccd_number );
```

Explanation:

Initializes CCD hardware; returns TRUE if hardware is present FALSE otherwise. If hardware is not detected the driver will perform hardware emulation as much as possible which is very useful for software testing.

```
//-------------------------------------------------------------------------
Function:  CCD_SET_EXPOSURE_TIME          301

Example:

byte_long     ccd_pass;

   ccd_pass.byte0 = 1;       /* ccd number */
   ccd_pass.long0 = 1000L;   /* time in milliseconds */

   ( void ) ccddriver( DRV_SET_EXPOSURE_TIME, &ccd_pass );
```

Explanation:

This function sets the time in milliseconds which will be used for all subsequent acquisitions.

```
//-------------------------------------------------------------------------
Function:  CCD_SET_AREAS                  304

Example:

int acq_size;

ccd_user_struct ccd_user_data;

    acq_size = *(int *) ccddriver( CCD_SET_AREAS, &ccd_user_data );
```

Explanation:

Provides pointers to user data areas. "ccd_user_data" must always be available after this call. User data buffer(s) must be at least "acq_size" integers in length.

NOTE: CCD_SET_AREAS sets "my_areas[0...number_of_areas].data_ptr" to NULL The program must now assign them to point to the data spaces allocated.

See "ccd_user_struct" for details.

```
//-------------------------------------------------------------------------
Function:  CCD_SET_TEMPERATURE            307

Example:

byte_word     ccd_pass;

   ccd_pass.byte0 = 1;       /* ccd number */
   ccd_pass.long0 = 0;       /* temperature in deg K */

   ( void ) ccddriver( CCD_SET_TEMPERATURE, &ccd_pass );
```

Explanation:

Sets the CCD to the temperature requested in degrees K. Use CCD_READ_TEMPERATURE to determine stability; this typicaly takes 20 minutes. NOTE: Reinitialize with HWINIT.BAT after a temperature change. This implies that the driver should be unloaded and reloaded to read new HWINIT parameters written to CCD.INB.

```
//-------------------------------------------------------------------------
Function:  CCD_READ_TEMPERATURE           308

Example:

byte ccd_number = 1;
int             temperature_1;

   temperature_1 = *(long *) ccddriver( CCD_READ_TEMPERATURE, &ccd_number
);
```

Explanation:

Returns the CCD head temperature in degrees K.

```
//-------------------------------------------------------------------------
Function:  CCD_READ_CHIP_STUFF            310

Example:

ccd_tsr_struct chip_data;

  chip_data.ccd_number = 1;
  ( void )ccddriver( CCD_READ_CHIP_STUFF,&chip_data );

Explanation:

   Returns hardware specific information.

See "ccd_tsr_struct" starting on page  for details.


//-------------------------------------------------------------------------
Function:  CCD_GO                         311

Example:

byte ccd_number = 1;

   ( void ) ccddriver( CCD_GO, &ccd_number );
Explanation:

    Starts the data acquisition sequence of:
       close shutter,
       perform number_of_flushes
       start integration - open shutter,integrate, close shutter
       transfer data from chip to RISC memory

NOTE: The actual execution of this sequence relies on calls to CCD_BUSY;


//-------------------------------------------------------------------------
Function:  CCD_STOP                        314

Example:

byte ccd_number = 1;

   ( void ) ccddriver( CCD_STOP, &ccd_number );

Explanation:

    Stops any CCD operation in process


//-------------------------------------------------------------------------
Function:  CCD_GO_BLANK                   322

Example:

byte ccd_number = 1;
```

```
   ( void ) ccddriver( CCD_GO_BLANK, &ccd_number );
```

Explanation:

```
    Starts the data acquisition sequence of:
       close shutter
       perform number_of_flushes
       start integration - integrate (Shutter is NOT opened)
       transfer data from chip to RISC memory
```

NOTE: The actual execution of this sequence relies on calls to CCD_BUSY;

```
//-------------------------------------------------------------------------
Function:  CCD_BUSY                       312
```

Example:

```
byte ccd_number = 1;
int     busy;

    busy = *(int *) ccddriver( CCD_BUSY, &ccd_number );
```

Explanation:
  Steps the CCD_GO sequence to the next state. Returns busy = next_state(!= 0) until done (== 0).

```
//-------------------------------------------------------------------------
Function:  CCD_READ_IMAGE                 315
```

Example:

```
byte ccd_number = 1;
    ( void ) ccddriver( CCD_READ_IMAGE, &ccd_number );
```

Explanation:

  Transfers 1 serial row of data into the storage area specified in "ccd_user_data". See CCD_SET_AREAS for details.

The program must perform multiple calls to this function until the entire image is transfered.

```
//-------------------------------------------------------------------------
Function:  CCD_READ_SCAN                  316
```

Example:

```
byte_word area_number;

area_number.byte0 = 1; /* CCD number */
area_number.word0 = -1; /* area number of -1 = read ALL areas */

   ( void ) ccddriver( CCD_READ_SCAN, &area_number );
```

Explanation:

Transfers data for "area_number" into user allocated storage specified in "ccd_user_data". If area_number = -1, ALL scan data will be transfered.

NOTE: This function can be randomly addressed by "area_number" but speed may be sacrificed.

NOTE: Transfer fastest if all of the storage is allocated at once and read ALL areas.

See CCD_SET_AREAS for details.

```
//-------------------------------------------------------------------------
Function:  CCD_RESET_IMAGE                317
```

Example:

```
byte ccd_number = 1;
   ( void ) ccddriver( CCD_RESET_IMAGE, &ccd_number );
```

Explanation:

Resets internal memory pointers so that the next call to CCD_READ_IMAGE will start at the beginning of the image. This is useful for multiple reads of the data from RISC memory for display purposes etc.

```
//-------------------------------------------------------------------------
Function:  CCD_RESET_SCAN                 318
```

Example:

```
byte ccd_number = 1;
   ( void ) ccddriver( CCD_RESET_SCAN, &ccd_number );
```

Explanation:

Resets internal memory pointers so that the next call to CCD_READ_SCAN will start at the beginning of the 1st area. This is useful for multiple reads of the data from RISC memory for display purposes etc.

```
//-------------------------------------------------------------------------
Function:  CCD_READ_NEXT_SCAN             319
```

Example:

```
byte ccd_number = 1;
   ( void ) ccddriver( CCD_READ_NEXT_SCAN, &ccd_number );
```

Explanation:

Transfers data sequentially from the next area into user allocated storage specified in "ccd_user_data".

NOTE: This function returns data areas in sequence. The program must call CCD_RESET_SCAN first to initialize the internal area counter.

NOTE: This method of data transfer is slower than if ALL areas are read at once (see CCD_READ_SCAN with area number = -1), but may be faster than calling

CCD_READ_SCAN for 1 area at a time. The speed will depend upon the CCD chips physical read out register direction.

See CCD_SET_AREAS for details.

```
//-------------------------------------------------------------------------
Function:  CCD_OPEN_SHUTTER              320

Example:

byte ccd_number = 1;
   ( void ) ccddriver( CCD_OPEN_SHUTTER, &ccd_number );

Explanation:

  Opens the CCD shutter.


//-------------------------------------------------------------------------
Function:  CCD_CLOSE_SHUTTER             321

Example:

byte ccd_number = 1;
   ( void ) ccddriver( CCD_CLOSE_SHUTTER, &ccd_number );

Explanation:

  Closes the CCD shutter.
```

Commutations are a JY generalization of the OPEN/CLOSE shutter commands. If the programmer has experience programming with other JY/ISA/SPEX drivers they are the same with the CCD shutter being commutation number 1; if the programmer is not familiar with this convention these calls may be ignored.

```
//-------------------------------------------------------------------------
Function:       CCD_GO_BLAST             329

Example:

byte_word     ccd_pass;

   ccd_pass.byte0 = 1;       /* ccd number */
   ccd_pass.word0 = 1;       /* number of blast cycles */

   ( void ) ccddriver( CCD_GO_BLAST, &ccd_pass );

Explanation:

  Sets the number of acquisition for the CCD to acquire in blast mode. Once
the CCD_GO_BLAST command has been sent, monitor the acquisition progress with
CCD_BUSY. As soon as first blast acquisition is finished retrieve the data and
reissue the CCD_BUSY command.


//-------------------------------------------------------------------------
Function:       COMMUTATION_INIT               190
```

Example:

```
   (void) ccddriver( COMMUTATION_INIT, NULL );
```

Explanation:

    This function initializes the shutter driver calls.

```
//-------------------------------------------------------------------------
Function:       COMMUTATION_SETUP               191

Example:

typedef struct
         {
         byte  byte0;
         word  word0;
         word  word1;
         word  word2;
         word  word3;
         word  word4;
         } byte_multi_word;

byte_multi_word shutter_parms;

   shutter_parms.byte0 = 1;        /* Must always be 1 */
   shutter_parms.word0 = SHUTTER;  /* Type */
   shutter_parms.word1 = 2;        /* Number of possible states */

   shutter_parms.word2 = SHUTTER_CLOSED;        /* Requested State */
   shutter_parms.word3 = 0;                     /* NOT_USED */
   shutter_parms.word4 = 0;                     /* NOT_USED */
   (void) ccddriver( COMMUTATION_SETUP, &shutter_parms );
```

Explanation:

    This function sets the parameters for next COMMUTATION_GO command to this device. The first 3 parameters must always be 1, 1, and 2, the fourth parameter is either 1 or 0 depending on whether it is necessary to open or close the shutter.

```
//-------------------------------------------------------------------------
Function:       COMMUTATION_GO                  192

Example:

byte  shutter_num;

   shutter_num = 1;                             /* Must always be 1 */
   (void) ccddriver( COMMUTATION_GO, &shutter );
```

Explanation:

    This function moves the shutter to the position specified by a previously executed COMMUTATION_SETUP command.

```
//-------------------------------------------------------------------------
```

Function: COMMUTATION_STATUS 195

Example:

```
byte_multi_word shutter_status;
unsigned char   shutter_num;

   shutter_num = 1;                              /* Must always be 1 */
   shutter_status = ccddriver( COMMUTATION_STATUS, &shutter_num );
```

Explanation:

This function returns the current state of the shutter in the structure shutter_status.

Definitions of Numbered Codes:

Setup and Communications Error Codes

NO_PROBLEM	0
HARDWARE_PROBLEM	1
FUNCTION_NOT_AVAILABLE	2
PARAMETER_PROBLEM	3
NOT_INITIALIZED	4
RECEIVE_ERROR	5
TRANSMIT_ERROR	6
BAD_CONFIRMATION	7
UNKNOWN_CONFIRMATION_ERROR	8
FRAMING_ERROR	9
PARITY_ERROR	10
OVERRUN_ERROR	11
COM_PORT_ERROR	12
BAUD_RATE_ERROR	13
COM_PARAM_ERROR	14
RCV_TIME_OUT_ERROR	15

CCD Low Level Error Codes:

CCD_OK	NO_PROBLEM
CCD_NULL_USER_POINTER	20
CCD_NOT_ENOUGH_MEMORY	21
CCD_ALTPARAM	22
CCD_LOAD	23
CCD_READPROG	24
CCD_TIMEOUT	25
CCD_ZEROLOOP	26

Commutation Devices:

SHUTTER_CCD	1

Commutation Types:

SHUTTER_TYPE	1

Commutation States:

SHUTTER_OPEN	1
SHUTTER_CLOSED	0

Commutation (Shutter) Function Numbers:

COMMUTATION_INIT	190
COMMUTATION_SETUP	191
COMMUTATION_GO	192
COMMUTATION_STATUS	195

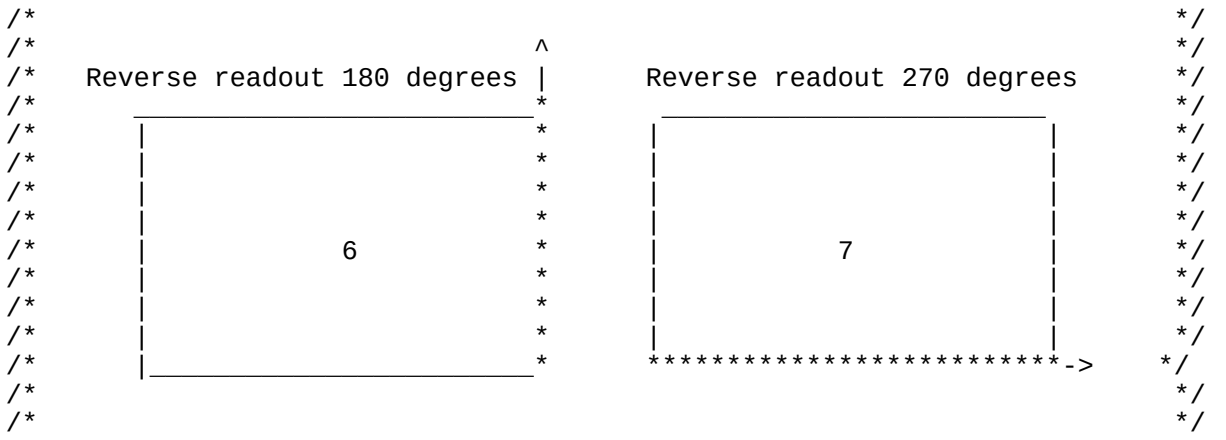
Acquisition Formats:

Image_format	0
Region_format	1

Type Definitions:

```
#pragma pack(1)

typedef unsigned char   byte;
typedef unsigned int    word;

typedef struct
   {
   char  version[16];        /* driver version  */
   char  id[16];             /* driver id       */
   }  driver_parms;

typedef struct
   {
   byte  byte0;
   byte  byte1;
   } byte_byte;

typedef struct
   {
   byte  byte0;
   word  word0;
   } byte_word;

typedef struct
   {
   byte  byte0;
   long  long0;
   } byte_long;

/*__For JY Commutations ____________________________________________________*/

typedef struct
   {
   byte  byte0;
   word  word0;
   word  word1;
   word  word2;
   word  word3;
   word  word4;
   } byte_multi_word;
/*_____________________________________________________________________________*/

typedef struct
   {
/* read from file: ccdload.ini */
   byte           ccd_number;

   int            port;

   int            total_active_x_pixels;
   int            total_active_y_pixels;

   int            num_serial_pxls_before_active;
   int            num_serial_pxls_after_active;
   int            num_parallel_rows_before_active;
```

```
   int            num_parallel_rows_after_active;
   byte           register_loc_and_direction; /* 0, 90, 180, 270 degrees */
/*                                                                        */
/*         readout register location and direction                        */
/*         add one from each of the following:                            */
/*               register location =     0       left                    */
/*                                      1       top                       */
/*                                      2       right                     */
/*                                      3       bottom                    */
/*                                                                        */
/*         direction is relative to our standard configuration            */
/*         with the readout register in the left position                 */
/*               direction         =     0    clockwise                  */
/*                                       4    counter-clockwise         */
/*                                                                        */
/*                                                                        */
/*       ^                                                                */
/*       |  Std Config 0 degrees                  90 degrees              */
/*       *_____________________________          ************************->   */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *              0             |         |           1            |     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *____________________________|         |________________________|     */
/*                                                                        */
/*                                                                        */
/*                                                                        */
/*                                                                        */
/*                 180 degrees                          270 degrees       */
/*       _____________________________*          _________________________     */
/*       |                            *         |                        |     */
/*       |                            *         |                        |     */
/*       |                            *         |                        |     */
/*       |                            *         |                        |     */
/*       |              2             *         |           3            |     */
/*       |                            *         |                        |     */
/*       |                            *         |                        |     */
/*       |                            *         |                        |     */
/*       |____________________________*      <-************************     */
/*                                    |                                   */
/*                                   V                                    */
/*                                                                        */
/*                                                                        */
/*        Reverse readout 0 degrees       Reverse readout 90 degrees      */
/*       _____________________________    <-************************     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *              4             |         |           5            |     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *                            |         |                        |     */
/*       *____________________________|         |________________________|     */
/*       |                                                                */
/*       V                                                                */
```




```
   int            min_temperature;
   int            max_temperature;

   long           min_shutter_time;
   long           max_shutter_time;

   word           min_gain;
   word           max_gain;

   int            h_pixel_spacing;
   int            v_pixel_spacing;

      /* calculated in ccd_init from above info */
   int            total_parallel_pixels; /* includes all possible pixels */
   int            total_serial_pixels;   /* includes all possible pixels */

      /* read from file: ccd.inb */
      /* may also be changed by a driver call */
   word           double_correl_integr_time;

   } ccd_tsr_struct;

/*_____________________________________________________________________________*/
typedef struct
   {
   unsigned int         *data_ptr;

   int                  x_origin,  /* offset */
                        y_origin,  /* offset */
                        size_x,    /* width  */
                        size_y,    /* height */
                        bin_x,
                        bin_y;

   } ccd_area_struct;

/*_____________________________________________________________________________*/
typedef struct
   {
/* passed in driver calls */
   byte           ccd_number;
   byte           acquisition_format; /* image = 0, region(scan) = 1 */
   int            number_of_areas;    /* when in region(scan) mode   */
   ccd_area_struct *area_ptr;
   } ccd_user_struct;
```

```
#pragma pack()
```

Production Code Examples:

Included on the disk is a fully functional example program written in Microsoft Quick C. This program file is QDCCD.C. Along with it are all the files necessary to build it. This should serve as a good starting point for a new program.

```
#define CCD_REGISTER_LONG 0x01

#define  MAX_USER_AREAS  10   /* User size; not limited in driver */
/* NOTE: MAX_USER_AREAS is a user parameter; the driver allocates any
         necessary storage based on number_of_areas */

void get_ccd_data( void )
{
int   busy, row, size_x, size_y, hardware, acq_size, rows_to_read;
long  time_out, end_time;

typedef struct
         {
         char  version[16];           /* driver version */
         char  id[16];                /* driver id      */
         } driver_parms;

driver_parms    *drvparms;

byte ccd_number;
byte_long ccd_exp_time;
byte_word ccd_flushes;

ccd_tsr_struct  chip_data;

ccd_user_struct         my_data;
ccd_area_struct         my_areas[ MAX_USER_AREAS ];
word                    my_image_buff[ 2048 ];

   drvparms = ccddriver( DRV_INITIALIZE, NULL );

   ccd_number = 1;      /* CCD number; always 1 */
   hardware = *(int *)ccddriver( CCD_INIT, &ccd_number );

   chip_data = (ccd_tsr_struct *)ccddriver(CCD_READ_CHIP_STUFF,
&ccd_number);

   size_x = chip_data.total_active_x_pixels;
   size_y = chip_data.total_active_y_pixels;

   ccd_exp_time.byte0 = 1; /* CCD number; always 1 */
   ccd_exp_time.long0 = exposure_time;
   ( void ) ccddriver( CCD_SET_EXPOSURE_TIME, &ccd_exp_time );

   ccd_flushes.byte0 = 1; /* CCD number; always 1 */
   ccd_flushes.word0 = number_of_flushes;
   ( void ) ccddriver( CCD_SET_NUMBER_OF_FLUSHS, &ccd_flushes );

   my_data.ccd_number = 1;
   my_data.acquisition_format = 0;
   my_data.number_of_areas = 1;
```

```
   my_data.area_ptr = my_areas;
   my_areas[0].x_origin = 0;
   my_areas[0].y_origin = 0;
   my_areas[0].size_x = size_x;
   my_areas[0].size_y = size_y;
   my_areas[0].bin_x = 1;
   my_areas[0].bin_y = 1;

   acq_size = *(int *) ccddriver( CCD_SET_AREAS, &my_data );

/* NOTE: CCD_SET_AREAS sets "my_areas[0].data_ptr" to NULL
   must now assign it to point to the data space allocated */

   my_areas[0].data_ptr = my_image_buff;

   ( void ) ccddriver( CCD_GO, &ccd_number );

   abort = FALSE;        /* global user flag */
   time_out = 2L * exposure_time;
   end_time = time_now() + time_out; /* time_now returns current time
                                        in milliseconds as a long */
   do
      {
      busy = *(int *) ccddriver( CCD_BUSY, &ccd_number );

      if ( key_board_hit() )             /* process user input */
         process_user_input();
      if ( end_time < time_now() )       /* check for time out */
         {
         display_an_error("Time Out", time_out );
         abort = TRUE;
         break;
         }
      }
   while ( busy  && !abort);       /* abort can be set by user to cancel
                                      the current acquisition */
   if ( abort )  /* user abort or time out */
      return;
   if ( chip_data.register_loc_and_direction & CCD_REGISTER_LONG )
      {
      rows_to_read = my_areas[0].size_y / my_areas[0].bin_y;
      }
   else
      {
      rows_to_read = my_areas[0].size_x / my_areas[0].bin_x;
      }
   /**  Reset image transfer back to 1st serial row **/
   ( void ) ccddriver(CCD_RESET_IMAGE, &ccd_number );

   /* Now get each row (line) of the image */
   for ( row = 0; row < rows_to_read ; row++ )
      {
        /* get a row of data */
        ( void ) ccddriver( CCD_READ_IMAGE, &ccd_number );
        /* do something with "acq_size" points of data in
           "my_image_buff" */
      }
}
//---------------------------------------------------------------------------
```

COMMAND SET STRUCTURE:

The controller family supported by this command set has been designed with a multi-purpose interface. This interface will communicate with a simple ASCII "terminal" or an "intelligent" computer program.

When you will be sending commands from a computer program, a command can be issued to change to the "intelligent" communications mode. This stops the character strings intended for the terminal display, and enables more useful responses from the CCD controller.

IEEE 488 Communication with a Computer:

Please refer to the documentation provided with your computer's IEEE 488 interface for information about how to send the various characters.

IEEE 488 can take command of the controller at any time by asserting the REM line. The system is automatically forced into the intelligent communications mode, where the controller expects to receive the commands as outlined later in the Command Descriptions. You must also send "O200 0<Null>", to transfer control to the main program that resides in the CCD controller. Then wait 0.5 second to be sure that the main program is ready to accept additional commands before proceeding.

Supported IEEE 488 Computer Interface Boards:

The IEEE 488 example programs work with several of the National Instruments PC interface boards.

- GPIB-PCII/PCIIA 488.2 Interface board: The driver supplied by National should be version 1.2 or newer, and their BASIC support disk should be version 2.0 or newer.

- Older GPIB-PCIIA boards require National's revision C13 or newer software.

- AT-GPIB 488 boards require National's revision E7 or newer software.

- AT-GPIB 488.2 board: Must be version 2.1.1 software, and their BASIC support disk version 2.2 or newer.

- GPIB-PCIII board: this model must be replaced with one of the above. Contact your local National Instruments dealer with regard to their current replacement program.

There are other boards by National and other suppliers for IBM compatible and MacIntosh computers. Many of these boards can function in *SIMILAR* fashion, however the CCD3000.EXE communicates specifically with the National Instruments driver therefore we **do not** support or guarantee reliable communications with other boards and software, we **strongly** recommend that you use the National Instruments products as described above.

Establishing GPIB Communications:

The IEEE board and it's associated software driver must be installed in your computer as per National Instruments' instructions. The driver must be installed via your computer's CONFIG.SYS file.

This set up assumes that the National Instruments software driver has the PCII board name as GPIB0 and the first device name as DEV1. Run the IBCONF program and set the configuration as follows:

GPIB0		**DEV5**	
Primary GPIB Address	0	Primary GPIB address	5
Secondary GPIB Address	None	Secondary GPIB address	None
Timeout Setting	T3s	Timeout Setting	T10s
EOS byte	00H	EOS byte 0Dh	
Terminate read on EOS	no	Terminate read on EOS	yes
Set EOI with EOS on write	no	Set EOI with EOS on write	no
Type of compare on EOS	7-bit	Type of compare on EOS	7-bit
Set EOI w/ last byte of write	yes	Set EOI w/ last byte of write	yes
System controller	yes	Repeat addressing	no
Assert REN when SC	no		
Enable auto serial polling	yes		
Timing	500 ns		
Enable 488.2 protocols	yes		
CIC protocols	no		
Handler Type	PC2		
Interrupt Setting	none		
Base I/O address	02B8H		
DMA channel	1		

The above are default settings.

The part of your program that will establish communications must follow the steps outlined in the "IEEE 488 Start Up Procedure" flow chart.

Note that timeout settings vary by command. In most cases 300 milliseconds is sufficient. Longer timeout recommendations are given, for the commands that need them, in the Command Descriptions Section.

To test GPIB communications:

This test assumes that you have correctly completed the GPIB set-up above.

Connect your GPIB cable between the National Instruments board in your computer and the CCD3000 controller. If other devices are to be used on the same bus, it is recommended that they be disconnected temporarily, to reduce the possible sources of problems while establishing communications for the first time.

From the directory where the National Instruments programs reside, Run IBIC, and issue the following commands at the **:** prompt.

IBFIND GPIB0	Finds the PCII board in the PC
IBFIND DEV5	Finds the CCD3000 controller at address 5
IBWRT " "	Send one space character (must be enclosed in Quotation marks)
IBRD 1	Read 1 character.

If you have successfully communicated, you should receive a B or an F. If you have an error message displayed, refer to the National Instruments documentation to interpret it.

Preparing to program via IEEE 488:

After success in communicating using the National Instruments hardware and software you may proceed to command the controller using the Programmer's Command Set.

There is a READ.ME file on the support diskette that may contain further, updated information.

If you construct programs based on the Command Set, we strongly recommend that you add prudent error trapping and protection features to your program to protect your system and enhance ease-of-use.

IEEE 488 Communications Startup:

The part of your program that will establish communications must follow the steps outlined in the IEEE 488 Start Up Procedure flow chart below.

When the controller is addressed on the IEEE 488 bus, it automatically sets itself in the intelligent communications mode and you need only establish whether you are talking to the BOOT or the MAIN internal controller program.

Send the `where am I' command, "<Space>", and the controller will respond with "B" for boot, or "F" for main. This tells you which internal program is running in the controller.

If you receive "B", you are talking to the BOOT program. Send "O2000" plus the "<Null>" character to transfer to the controller's MAIN program. Wait 0.5 second to be sure that the main program is ready to accept additional commands before proceeding.

If you receive the "F" character, you are talking to the MAIN program. This means that the controller has previously been run by a program. In this case you may not have to send the INIT and SET commands described later. Instead, you may wish to read back the previous positions into your program.

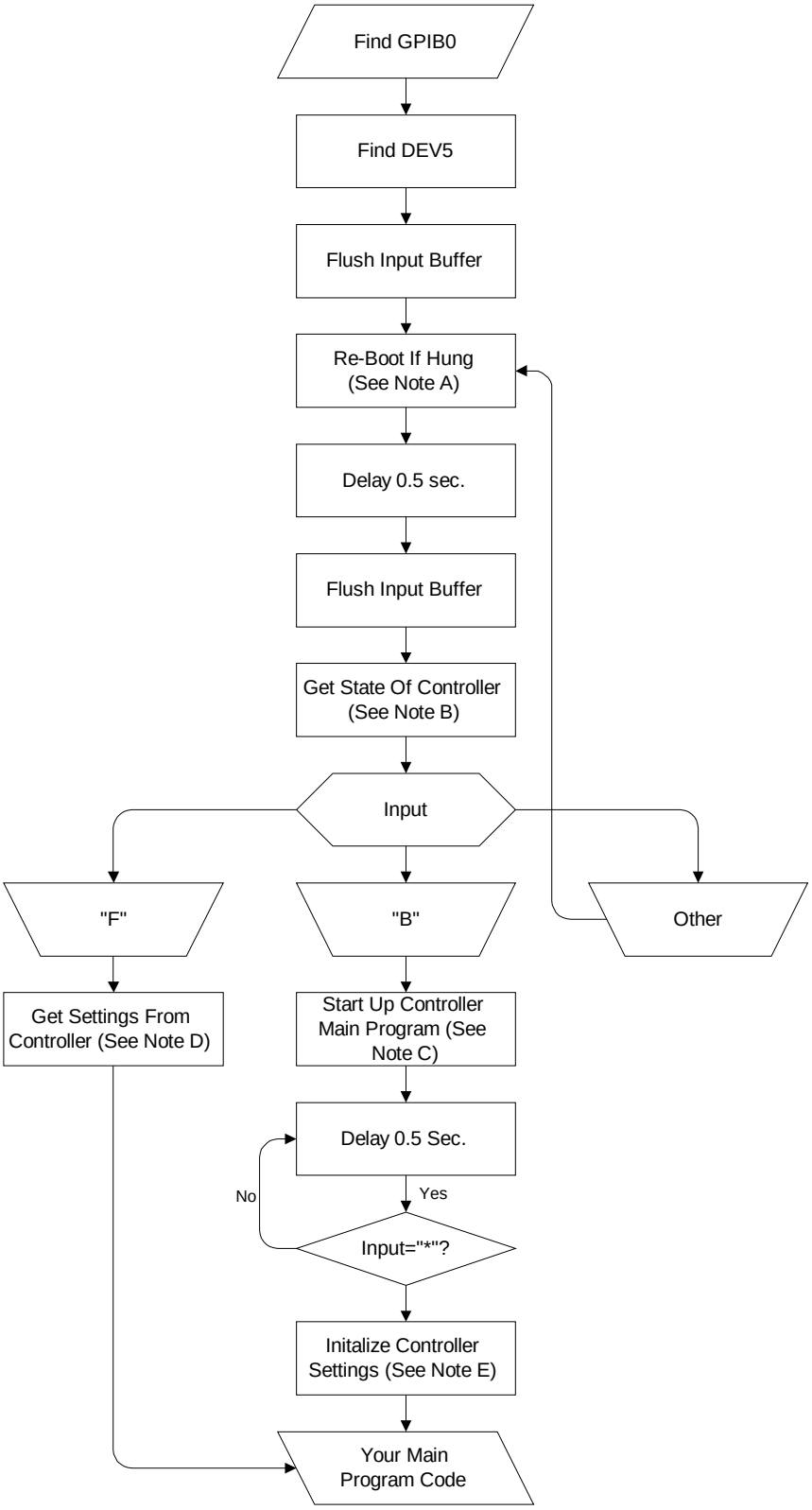
In intelligent communications mode, the terminal prompts are turned off. Commands are acknowledged with single characters.

Re-booting a Controller

If your program exits before you complete a command, the controller will hang. It will wait for the rest of the command input. This condition can be cleared by re-powering the controller.

Assuming that you are communicating in the intelligent mode, you may send the pseudo-command "<222>" as a single byte to re-boot the spectrometer controller. The <222> is ignored if the spectrometer controller is not hung waiting for additional parameters. Pseudo-commands do not cause the spectrometer controller to send back any response character.

You may want to re-boot the controller at some time, without manually turning it off and back on. To do this, intentionally send it an incomplete command.



Notes on IEEE-488 Start Up Procedure

A: Send decimal value "<222>". This will force a re-boot if hung from an incomplete command.

B: Send WHERE AM I command "<Space>"; response will be "B" (for BOOT) or "F" (for MAIN) depending on the previous state of the CCD3000 controller.

C: Send "O2000<Null>". To transfer control from the BOOT to the MAIN program. You must send the "<Null>". Wait 0.5 second.

D: You can read your last position etc. from the spectrometer controller. You do not have to re-initialize the CCD3000 controller.

E: Initialize controller. Data tables must be loaded into the controller memory. See **TABLE LOADING PROCEDURE** on next page.

Table Loading Procedure

Example using ECONVERT.TAB

Note: All tables must be loaded for controller to initialize properly.

Content/Meaning

- Table Size, 159 Long (4 bytes) follows.
- Pixel Table, each line holds 4 bytes worth of data.
- Numbers vary between table and version of table.

Line #	Table			
1	9F	00	00	00
2	01	00	33	01
3	02	00	33	01
4	03	00	33	01
M	M	M	M	M
160	00	00	71	01
	Chip Select + 0 (R_0)	Chip Select + 1 (R_1)	Chip Select + 2 (R_2)	Chip Select + 3 (R_3)

For ECONVERT.TAB

address offset = 0x1400
chip select = 0

To load ECONVERT, the following steps must be taken:

1. Send Z340,5120,0,159<CR>
2. Get the confirm character and send R_0 as binary data of 159 bytes
3. Send Z340,5120,1,159<CR>
4. Get the confirm character and send R_1 as binary data of 159 bytes
5. Send Z340,5120,2,159<CR>
6. Get the confirm character and send R_2 as binary data of 159 bytes
7. Send Z340,5120,3,159<CR>
8. Get the confirm character and send R_3 as binary data of 159 bytes

Load Sequence

STIDLE.TAB

address offset = 0x00
chip select = 0

SERWCONV.TAB
address offset = 0x400
chip select = 0

SERCLEAR.TAB
address offset = 0x800
chip select = 0

SERBIN.TAB
address offset = 0xC00
chip select = 0

PARTRANS.TAB
address offset = 0x1000
chip select = 0

BCONVERT.TAB
address offset = 0x1400
chip select = 0

ECONVERT.TAB
address offset = 0x1800
chip select = 0

NIDLE.TAB
address offset = 0x1C00
chip select = 0

Communications Conventions:

1. This is a definition of the communications that should occur when a computer interfaces with the spectrometer controllers.

2. Whenever you see <CR>, it means to use ASCII Carriage Return. (13 in DECIMAL).

3. Any string that is placed inside of a pair of double quotes, i.e. "abcd" means that you should send all characters exactly as shown inside the double quotes. You should include spaces, But do not include the double quote characters. Also if you see a character symbolized using <> in a string, you send the character only, not the symbols. For example: if you see"1,Ø,<Null>", you should send only 5 ASCII characters: the 1, the comma, the Ø, another comma, and the Null character (decimal Ø).

4. Anything placed inside of a pair of square brackets, i.e. [Ø..1] indicates the valid range of the parameter associated with it.

Command Syntax and Confirmation :

This section outlines the rules of syntax required to successfully send commands and recognize confirmation responses that will inform you that the spectrometer controller has or has not received a valid command string.

Standard Commands:

As a prerequisite to sending operational commands to your spectrometer controller, you must establish communications first (refer to previous sections). Only after communications have been successfully established can other commands can be sent to it.

All commands are ASCII text, unless specifically noted otherwise. The "Standard Commands" are only 1 character and are detailed in the command descriptions below. For commands requiring additional input, the command is sent, immediately followed by the relevant parameter(s). The command parameters form a string of characters representing the data that is sent or received.

Extended Commands:

The command set is not limited by the number of characters in the English alphabet.

The character "Z" has been assigned for access to extended commands. The first parameter

following this command is recognized as the number representing the extended command you wish to execute. Depending on the command number you send, you may be required to send more parameters following the command.

Otherwise, extended commands are handled in the same way as the standard commands above.

Pseudo-Commands:

These commands perform some special utility functions. The syntax is the same as standard single byte commands, except that the bytes sent as commands are not text. They are values such as <222>. In this document, they are expressed as decimal values, between the < and > symbols. The pseudo-command to re-boot the spectrometer controller is expressed as <222>. Another difference is that pseudo commands do not generate a response character from the CCD controller.

CCD command set

CCD_INIT **Z300**

Initializes CCD hardware. If hardware is not detected the driver will perform hardware emulation as much as possible which is very useful for software testing. This command must be called first.

Input format	Output format
"Z300,PARAM<CR>" PARAM: CCD number - always 0	"o" + "RESULT<CR>" RESULT: hardware status - 1 for present, 0 otherwise
Example	
Send: "Z300,0<CR>"	Receive: "o" + "1<CR>"

CCD_SET_EXPOSURE_TIME **Z301**

Sets the CCD integration time in milliseconds.

Input format	Output format
"Z301,PARAM1,PARAM2<CR>" PARAM: 1. CCD number - always 0 2. integration time (msec)	"o"
Example	
Send: "Z301,0,1000<CR>"	Receive: "o"

CCD_SET_GAIN **Z302**

Sets the CCD gain.

Input format	Output format
"Z302,PARAM1,PARAM2<CR>" PARAM: 1. CCD number - always 0 2. CCD gain	"o"
Example	
Send: "Z302,0,2<CR>"	Receive: "o"

CCD_READ_GAIN Z303

Returns the current gain setting.

Input format	Output format
"Z303,PARAM<CR>" PARAM: CCD number - always 0	"o" + "RESULT<CR>" RESULT: CCD gain
Example	
Send: "Z303,0<CR>"	Receive: "o" + "2<CR>"

CCD_SET_NUMBER_OF_FLUSHES Z305

Sets the number of flushes of the CCD which will occur prior to starting an acquisition.

Input format	Output format
"Z305,PARAM1,PARAM2<CR>" PARAM: 1. CCD number - always 0 2. number of flushes	"o"
Example	
Send: "Z305,0,1<CR>"	Receive: "o"

CCD_SET_TEMPERATURE Z307

Sets the CCD to the specified temperature (degrees K multiplied by 100). Use CCD_READ_TEMPERATURE to determine stability, this typically takes 20 minutes.
NOTE: you should reinitialize hardware after a temperature change; details unknown.

Input format	Output format
"Z307,PARAM1,PARAM2<CR>" PARAM: 1. CCD number - always 0 2. temperature (°K × 100)	"o"
Example	
Send: "Z307,0,29000<CR>"	Receive: "o"

CCD_READ_TEMPERATURE Z308

Reads CCD temperature in degrees K multiplied by 100.

Input format	Output format
"Z308,PARAM<CR>" PARAM: CCD number - always 0	"o" + "RESULT<CR>" RESULT: CCD temperature (°K × 100)
Example	

Send: "Z308,0<CR>"	Receive: "o" + "29000<CR>"

CCD_READ_CHIP_STUFF **Z310**

Returns CCD hardware specific information.

Input format	Output format
"Z310,PARAM<CR>" PARAM: CCD number - always 0	"o" + "RESULT1,...,RESULT18<CR>" RESULT: 1. port 2. total number of active x-pixels 3. total number of active y-pixels 4. number of serial pixels before active 5. number of serial pixels after active 6. number of parallel rows before active 7. number of parallel rows after active 8. readout register location and direction 9. minimum temperature ($°K \times 100$) 10. maximum temperature ($°K \times 100$) 11. minimum shutter time (msec) 12. maximum shutter time (msec) 13. minimum gain 14. maximum gain 15. horizontal pixel spacing ($\mu m \times 10^{-1}$) 16. vertical pixel spacing ($\mu m \times 10^{-1}$) 17. total parallel pixels 18. total serial pixels
Example	
Send: "Z310,0<CR>"	Receive: "o" + "848,1024,256,8,8,0,0,5,0,29000,0,400000000,0, 4,270,270,256,1040<CR>"

CCD_START **Z311**

Sets up the data acquisition sequence of:

1. close shutter
2. perform specified number of flushes (default - 1)
3. start integration (with open or closed shutter)
4. transfer data from chip to RISC memory

Input format	Output format
"Z311,PARAM1,PARAM2<CR>" PARAM: 1. CCD number - always 0 2. shutter flag - 1 if open during integration, 0 if closed	"o"
Example	
Send: "Z311,0,1<CR>"	Receive: "o"

CCD_STATUS **Z312**

Checks if an acquisition is finished or not.

Input format	Output format
"Z312,PARAM<CR>" PARAM: CCD number - always 0	"o" + "RESULT<CR>" RESULT: CCD acquisition status - non-zero integer if an acquisition is in progress, 0 if finished
Example	
Send: "Z312,0<CR>"	Receive: "o" + "2<CR>"

CCD_STOP **Z314**

Stops previously started acquisition.

Input format	Output format
"Z314,PARAM<CR>" PARAM: CCD number - always 0	"o"
Example	
Send: "Z314,0<CR>"	Receive: "o"

CCD_READ_IMAGE **Z315**

Transfer all the scan data from the controller using binary transfer conventions. The number of data points transferred is equal to the number returned from the CCD_GET_DATA_SIZE call plus 1 (Status byte, 1 data point = 2 bytes).

Input format	Output format
"Z315,PARAM<CR>" PARAM: CCD number - always 0	Binary data transfer
Example	
Send: "Z315,0<CR>"	Receive: Binary data

CCD_RESET_IMAGE **Z317**

Resets the controller so that the next CCD_READ_IMAGE call starts at the beginning of the image.

Input format	Output format
"Z317,PARAM<CR>" PARAM: CCD number - always 0	"o"
Example	

Send:	Receive:
"Z317,0<CR>"	"o"

CCD_SET_SHUTTER Z320

Opens or closes the CCD shutter.

Input format	Output format
"Z320,PARAM1,PARAM2<CR>" PARAM: 1. CCD number - always 0 2. shutter flag - 1 for open, 0 for close	"o"
Example	
Send: "Z320,0,1<CR>"	Receive: "o"

CCD_DEFINE_ACQ_FORMAT Z325

Sets up the type of acquisition (image or scan) and the number of areas for the acquisition. Only one area can be set in an image mode.

Input format	Output format
"Z325,PARAM1,PARAM2,PARAM3<CR>" PARAM: 1. CCD number - always 0 2. acquisition format (0 - image, 1 - scan) 3. number of areas	"o"
Example	
Send: "Z325,0,0,1<CR>"	Receive: "o"

CCD_DEFINE_AREA Z326

Defines physical location of a particular area on the CCD detector and the area's binning. Size and binning are specified in pixels.

Input format	Output format
"Z326,PARAM1,...PARAM8<CR>" PARAM: 1. CCD number - always 0 2. area number (starting from 0) 3. area's x-origin 4. area's y-origin 5. area's x-size 6. area's y-size 7. x-binning 8. y-binning	"o"
Example	
Send: "Z326,0,0,0,0,1024,256,1,1<CR>"	Receive: "o"

CCD_GET_DATA_SIZE Z327

Returns the recommended buffer size and the total number of data points plus one.

Input format	Output format
"Z327,PARAM<CR>" PARAM: CCD number - always 0	"o" + "RESULT1,RESULT2<CR>"
Example	
Send: "Z327,0<CR>"	Receive: "o" + "1024,262144<CR>"

CCD_WRITE_CHIP_STUFF Z328

Returns the number of data points in the largest scan area or in one image row and total number of data points for this acquisition.

Input format	Output format
"Z328,PARAM1,….PARAM19<CR>" PARAM: 1. CCD number - always 0 2. port (value is not important) 3. total number of active x-pixels 4. total number of active y-pixels 5. number of serial pixels before active 6. number of serial pixels after active 7. number of parallel rows before active 8. number of parallel rows after active 9. readout register location and direction 10. minimum temperature ($^{\circ}K \times 100$) 11. maximum temperature ($^{\circ}K \times 100$) 12. minimum shutter time (msec) 13. maximum shutter time (msec) 14. minimum gain 15. maximum gain 16. horizontal pixel spacing ($\mu m \times 10^{-1}$) 17. vertical pixel spacing ($\mu m \times 10^{-1}$) 18. total parallel pixels 19. total serial pixels	"0"
Example	
Send: "Z328,0,848,1024,256,8,8,0,0,5,0,29000,0,400000000,0,4,270,270,256,1040<CR>"	Receive: "o"

CCD_GO_BLAST **Z329**

Set the controller to take the specified number of acquisitions as fast as possible.

Input format	Output format
"Z329,PARAM1,PARAM2,<CR>" PARAM: 1. CCD number - always 0 2. Number of acquisitions	"o"
Example	
Send: "Z329,0,1<CR>"	Receive: "o"

CCD_WRITE_XDATA **Z340**

Setting the data memory of the controller.

Input format	Output format
"Z340,PARAM1,….PARAM4<CR>" PARAM: 1. CCD number - always 0 2. Chip select 3. Address to write 4. Size to write	"o"
Example	
Send: 1. "Z340,512,0,159<CR>" 2. Send data in binary transfer. (159 bytes in this example)	Receive: "o"

CCD_SET_MUX_AND_READ_ADC Z345
Use to read CCD temperature and other sensors.

Input format	Output format
"Z345,PARAM1,PARAM2<CR>" PARAM: 1. CCD number - always 0 2. Mux channel code CF Analog Ground CB ADC Reference C1 A_EXT C2 REF_RO C3 VOG C4 VABD C5 V5V25_RO C6 V15_RO C7 SET_CS C8 VTHERN C9 CCD_TEMP CA SINK_TEMP CØ STAGE1 CC STAGE2 CD STAGE3 CE STAGE4	"o" + "RESULT1<CR>"
Example	
Send: "Z345,0,C9<CR>"	Receive: "o" + 2 bytes To convert temperature to a real number, two cases: $K = (C9 - CF) \times \left(\frac{3 \times factor}{4915} \right)$ $K = \frac{(C9 - CF) \times 3 \times factor}{(CB - CF)}$ Case 2 is more accurate but requires one addition read. The factor for temperature is 1000, for all other parameters the factor is 1.

Binary transfer protocol.

Binary transfer takes place between the host computer and the controller. We can assign the names "Sender" and "Receiver" to them, depending on which unit sends or receives binary data. The protocol is presented below:

1. Issue the command (size of the transfer usually a part of the parameter list)
2. Get conformation
3. Send the data which has is equal to the size specified in Step 1.

Error codes.

In the case that the input from the host computer causes problem for the controller the latter will return symbolic warning that error has occurred. The warnings can be of the following formats:

1. "b" - an incomplete or erroneous command has been sent.
2. "e" + "ERR_CODE<CR>" - controller attempted operation, but error occurred.

ERR_CODE	Meaning
1	Hardware problem
2	Not available
3	Parameter problem
4	Not initialized
20	CCD: NULL user pointer
21	CCD: Not enough memory
22	CCD: Altparam
23	CCD: Load
24	CCD: Read program
25	CCD: Timeout
26	CCD: Zeroloop
30	PDA: Multiscan error
31	Remote: Not enough memory
32	Remote: No data available
33	Remote: Binary transfer error
34	Remote: Illegal call sequence

APPENDIX G: PROGRAMMING WITH THE WINDOWS DLL

INTRODUCTION

This document outlines the use and implementation of the ISA Spectrum One CCD driver for Windows. The section "Using the Driver" describes obtaining and using a device handle. The section "Source" provides documentation for the source code. Additional source documentation may be found in the CCDSRC help file provided with the source.

This driver provides all the functionality needed to setup acquisition and retrieve images from the camera. Some of the supported setup parameters include exposure time, flush count, double correlation integration time, active CCD surface regions, and temperature.

The driver supports the standard I/O controller board, the DMA I/O controller board (both polled and interrupt-driven), and hardware emulation. The ICcd interface provides a consistent presentation of the device no matter which of the aforementioned forms the device takes.

USING THE DRIVER

The abstract device interface handle is the only means by which the application can communicate with a device. This "magic cookie" is created by one of the driver's object creation functions CcdCreateDevice or CcdCreateEmulatorXXX. This handle is defined in C++ as a pointer to the abstract base class. This mechanism enforces interaction with the device without any knowledge of the particular object's interface implementation. No mechanism is provided which allows direct access to any of the data of the object that implements the interface. Note that for efficiency, direct access is allowed to the region buffers. See the Microsoft OLE 2 documentation in the Windows SDK for more information on OLE interfaces and the Component Object Model (COM).

Note: It is strongly recommended that API version 1.1 or higher is used.

Obtaining a device interface handle

There are four distinct implementations (i.e., classes) of the ICcd interface currently provided by the driver. They are the following:

- Emulator
- Standard I/O
- DMA I/O (polled)
- DMA I/O (interrupt-driven)

These may be broadly divided into two groups: hardware and emulated. The hardware devices provide ICcd implemented on hardware. The emulator devices implement ICcd in software.

```
STDAPI CcdCreateDevice(HCCDI *phccdi)
STDAPI CcdCreateEmulatorFromFile(LPCSTR lpszPath, HCCDI *phccdi)
```

Using a device interface handle

COM Interface

This interface is typically used in C++ applications but is also callable from any language that supports doubly indirected pointers to functions. It is very similar to the OLE Component Object Model (COM) interfaces with the exception that the interface does not have an IUnknown. The full COM specification (registration database entries, IUnknown, reference counting) was not implemented here since the base class can't be shared and the added complexity for the application to support OLE.

There are two interrelated 2-D coordinate systems in the driver. Both dimensions in each system are in units of pixels. The most visible is the logical coordinate system in which the API is defined. This coordinate system defines the origin as the upper-left pixel. The X-axis extends to the right, and the Y-axis extends downward. The internal coordinate system is relative to the readout register. Since the readout register may be in one of eight possible configurations, it is desirable to have the lowest layers absorb the burden of providing a logical view of the chip which does not vary with readout register orientation. The internal coordinate system defines two dimensions, termed serial and parallel. The serial dimension coincides with the readout register alignment. The parallel dimension is orthogonal to the serial. The camera basically defines three operations: serial shift, parallel shift, and A/D convert. All regions are stored internally as serial/parallel pairs that describe the shifts with and without A/D conversions before and after the region.

Pascal Interface

This interface is composed of the wrapper functions that are callable from C, Pascal, Visual Basic, or any language that can call exported functions in a DLL by name, pass parameters on the stack left-to-right, and accept return values in DX:AX register pair.

DATA STRUCTURES

This chapter documents the data structures used in the driver API.

CCD_POINT

Logical point of the CCD surface.

```
typedef struct {
      WORD x;
      WORD y;
} CCD_POINT;

x                 Specifies the horizontal coordinate
y                 Specifies the vertical coordinate
```

CCD_SIZE

Logical size of an area of the CCD surface.

```
typedef struct {
      WORD cx;
      WORD cy;
} CCD_SIZE;

cx                Specifies the horizontal count of pixels
cy                Specifies the vertical count of pixels
```

CCD_CHIPMETRICS

Characteristics of the CCD surface and chip.

```
typedef struct {
      CCD_SIZE sizActivePixels;
      UINT     nOrientation;
      CCD_SIZE sizPixelSpacing;
} CCD_CHIPMETRICS, FAR *CCD_LPCHIPMETRICS;

sizActivePixels   Number of logical active pixels.
nOrientation      Readout register orientation as defined in
                  ccdload.ini.
sizPixelSpacing   Physical distance between pixels (0.1 µm)
```

CCD_TEMPS

```
typedef struct {
      WORD ccd1;        // @field CCD temperature
      WORD sink;        // @field Sink temperature
      WORD vtherm;      // @field Thermostat set point
} CCD_TEMPS, FAR* CCD_LPTEMPS;

ccd1              CCD temperature
sink              Sink temperature
vtherm            Thermostat set point
```

CCD_PROP

This structure provides an extensible mechanism for manipulating CCD object properties while maintaining a consistent API.

```
typedef struct tagCCD_PROP
{
```

```
        DWORD id;

        union
        {
              UINT            cFlush;
              DWORD           dwExposureTime;
              DWORD           rgdwExposureTime[2];
              WORD            wTemperature;
              WORD            rgwTemperature[2];
              WORD            wGain;
              WORD            rgwGain[2];
              WORD            wDblCorTime;
              CCD_TEMPS       temps;
              CCD_CHIPMETRICS chipmet;
              BOOL            fShutter;
        };

  } CCD_PROP, FAR* CCD_LPPROP, const FAR* CCD_LPCPROP;
```

Property Identifier	Data Member Name	Access	Description
CCDPID_FLUSHCOUNT	cFlush	R/W	Number of flushes
CCDPID_EXPOSURETIME	dwExposureTime	R/W	Exposure time (in ms)
CCDPID_EXPOSURETIMERANGE	rgdwExposureTime[2]	R	Valid exposure time (in ms)
CCDPID_TEMPERATURESETPT	wTemperature	R/W	Temperature set point (in 0.1 ºK)
CCDPID_TEMPERATURERANGE	rgdwTemperature[2]	W	Valid temperature set point (in 0.1 ºK)
CCDPID_DBLCORTIME	wDblCorTime	R/W	Double correlation integration time
CCDPID_GAIN	wGain	R/W	Gain
CCDPID_GAINRANGE	rgwGain[2]	R	Valid gain settings
CCDPID_TEMPERATURES	temps	R	Detector temperatures (in 0.1 ºK)
CCDPID_CHIPMETRICS	chipmet	R	Chip characteristics
CCDPID_SHUTTER	fShutterClosed	R/W	Shutter state (closed/open)
CCDPID_BLASTINTERVAL	dwBlastInterval	R/W	Blast time interval (in ms)CCD3000 controller only
CCDPID_BLASTCOUNT	dwBlastCount	R/W	Blast cycle total. CCD3000 controller only
CCDPID_TRIGEROVERRIDE	fTriggerEnable	W	Enable/disable trigger. CCD3000 controller only

Table 1, CCD Properties

CCD_LOGRGN

Logical region of the CCD surface.

```
typedef struct {
      CCD_POINT   org;
      CCD_SIZE    ext;
      CCD_SIZE    bin;
      CCD_PRGNBUF pwData;
      CCD_SIZE    sizData;
} CCD_LOGRGN, const FAR* CCD_LPCLOGRGN;
```

```
org         origin
ext         extents (in pixels before binning)
bin         binning
pwData      Pointer to region's buffer (filled on output)
sizData     Dimensions of matrix allocated (filled on
            output)
```

CCD_AREA

This structure is available in API versions less than 1.1. New code should use CCD_LOGGRN instead.

Logical area of chip surface.

```
typedef struct {
      CCD_POINT   org;
      CCD_SIZE    ext;
      CCD_SIZE    bin;
} CCD_AREA;

org               origin
ext               extents (in pixels before binning)
bin               binning
```

CCD_REGIONINFO

This structure is available in API versions less than 1.1. New code should use CCD_LOGGRN instead.

Information on an area buffer.

```
typedef struct {
      CCD_SIZE sizExt;
      CCD_PRGNBUF pwData;
} CCD_REGIONINFO, FAR* CCD_LPREGIONINFO;

sizExt            Dimensions of matrix allocated
pwData            Pointer to region's buffer
```

STATUS CODES

The following list shows the status codes that are returned by various methods. Codes beginning with CCD_ are specific to the ICcd interface, other codes are general OLE status codes.

S_OK
The operation was successful.

S_FALSE
The operation was successful, but more work is needed. Busy will return this value as long as everything is going OK, but transfer is not yet complete.

E_ACCESSDENIED
Access to a given initialization file was not granted. The path may be invalid.

E_INVALIDARG
One or more arguments were invalid.

E_OUTOFMEMORY
Not enough memory to complete this operation.

E_HANDLE
An invalid handle was passed to a C/Pascal wrapper function. Note that no pointer validation occurs in the C++ interface since the handle is really a pointer to the object's v-table and we are not able to intervene in the virtual function invocation.

CCD_E_NOTCONFIGURED
The driver could not find the configuration information for the driver. This information is in the system.ini file for physical devices. See the configuration section of this document for details.

CCD_E_INVALIDINITFILE
An invalid initialization file was found during start-up. The files included in this list are:

- ccdload.ini
- ccd.inb
- flush32.d
- csettemp.d
- ctemps.d
- shut32.d
- c578col.d
- cshutter.d
- oshutter.d

CCD_E_HWNOTDETECTED
The hardware was not detected at the given port and type. See configuration section of this document for details.

CCD_E_PROGMEMTOOSMALL
The on-board program memory is too small to hold the programs.

CCD_E_DEVICETIMEOUT
The device did not become ready during the time-out interval. This interval is hardcoded at 5000 ms.

CCD_E_NOTRUNNING
Function sequence error. A call to some method was made while the driver did not have an operation is progress. An example of this is calling Busy or Stop prior to calling Go.

CCD_E_PROPNOTSUPPORTED
The given property identifier is not recognized or supported by this device.

CCD_E_REGIONPAGELOCK
The acquisition was aborted since the regions buffers could not be page-locked.

CCD_E_FIFOOVERFLOW
The FIFO on the DMA board overflowed. Data acquisition is aborted since the data in the region buffer would be corrupt. Also, we have lost a TC and can not reliable determine the end of acquisition.

CCD_E_REGIONNOTLOCKED
This status code is available only for API versions less than 1.1.
The region in RegionUnlock was not locked.

CCD_E_REGIONLOCKED
This status code is available only for API versions less than 1.1.
A region in SetAreas was locked, unable to set areas since there is an outstanding reference to a region buffer.

METHODS

All methods are declared as HRESULT __far __export. The various return codes are defined above by the status codes for the driver.

Note: The header file contains more methods than shown below. However at this stage, we will only support the listed interfaces.

Go(BOOL fBlank)
Initialize the data acquisition state machine.

Busy(UINT *puState)
Advance the data acquisition state machine.

Stop()
Abort acquisition in progress.

Release()
Release the device interface.

PropGet(CCD_PROP &prop)
Get a property. See the property data structure in this document for details.

PropSet(const CCD_PROP &prop)
Set a property

RegionSet(CCD_LOGRGN rgRgn[], UINT cRgn)
Define active regions on the chip. The regions MUST be defined with the following constraints. Any violation of these constraints may result in unpredictable camera

RegionReset()
Clear all regions of the chip and release region buffers. It is the applications responsibility to ensure it does not have any outstanding references to the region buffers.

CONFIGURATION

The driver uses information in the system.ini file for configuring the driver. The type of hardware is indicated by these settings. The section must be named [ISA CCD Driver]. The following keys in this section are used by the driver:

NOTE: All settings are specified in DECIMAL.

Path

Fully qualified path to initialization files (ccdload.ini, ccd.inb, D-files. There must not be a trailing "\" in the specification.

Port

Base I/O address of the board (decimal, not hex).

NOTE: The driver ignores the <path\ccdload.ini> base port specification.

DMA

Specifies which DMA channel the hardware uses.

If this entry is not present, the driver assumes the hardware is not capable of DMA (ie. standard I/O board).

IRQ

IRQ line used by the hardware. This entry is used by the driver in determining which interrupt vector to hook and which IRQ to acknowledge on the PIC.

If this entry is not present, the IRQ will not be used.

Here is an example section from a valid system.ini file:

```
[ISA CCD Driver]
debugflags=0
path=c:\dev\isa\ccd\inifiles
port=3616
dma=1
irq=5
```

Emulation
=========

The driver supports emulation. Use CcdCreateEmulatorFromXXXX functions to obtain an interface handle for an emulator.

To create an emulator from a file use:

```
CcdCreateEmulatorFromFile(<filename>, &pccd);
```

where <filename> is the name of an emulator definition file. A sample emulator definiton file is supplied (myccd.emu) that was made from an actual image. Actually, it was created from a bitmap that was created by an actual image. Use CcdBitmapToEmulator to create an emulator definition file from a bitmap. The implementation of this particular function is not very robust, but it should work with standard Windows 256-color bitmaps.

For example:

```
CcdBitmapToEmulator("c:\\dev\\isa\\ccd\\bitmaps\\ccdwin0.bmp",
"c:\\dev\\isa\\ccd\\bitmaps\\ccdwin0.emu"):
```

Emulators are also implemented as calculated values. The high-byte of the value is the x-coordinate of the pixels, and the low-byte is the y coordinate.

To create a synthesized emulator use:

```
CCD_SIZE siz = { 1024, 256 };
CcdCreateEmulatorFromSpec(5, &siz, &pccd)
```

Where siz is the logical dimensions of the active area, and the constant 5 indicates the optimal readout register orientation.

NOTE: Binning is ignored by the emulator.

EXAMPLE C PROGRAM

```
//    Note: This code is only intended as an example.
#include <windows.h>
#include <windowsx.h>
#include <ole2.h>
#include "ccdapi.h"
HCCDI           pDev = NULL;
CCD_LOGRGN      CCDRgn[20];
void main ();
void main ()
{
   CCD_PROP        CCDProp;
   UINT            uCCDState;
   int             iCount;

   CcdCreateDevice(&pDev);
   CcdStop(pDev);

   CCDProp.id = CCDPID_FLUSHCOUNT;
   CCDProp.cFlush = 1;
   CcdPropSet(pDev, &CCDProp);

   CCDProp.id = CCDPID_TEMPERATURESETPT;
   CCDProp.wTemperature = 140;
   CcdPropSet(pDev, &CCDProp);

   CCDProp.id = CCDPID_TEMPERATURES;
   CcdPropGet(pDev, &CCDProp);
   // 10 ms  integration time
   CCDProp.id = CCDPID_EXPOSURETIME;
   CCDProp.dwExposureTime = 10L;
   CcdPropSet(pDev, &CCDProp);
   CCDProp.id = CCDPID_CHIPMETRICS;
   CcdPropGet(pDev, &CCDProp);

      // Full image
      CCDRgn[0].org.x = 0;
      CCDRgn[0].org.y = 0;
      CCDRgn[0].ext.cx = CCDProp.chipmet.sizActivePixels.cx;
      CCDRgn[0].ext.cy = CCDProp.chipmet.sizActivePixels.cy;
      CCDRgn[0].bin.cx = 1;
      CCDRgn[0].bin.cy = 1;
   CcdRegionSet (pDev, CCDRgn, 1);
   for ( iCount=0; iCount<4; iCount++ )
      {
      CcdGo(pDev, FALSE );
      do
         {
         CcdBusy(pDev, &uCCDState);
         }
      while ( FALSE != uCCDState );
      uCCDState = FALSE;
      }

   CcdRelease(pDev);
}
```

INDEX

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