KPol control and data acquisition software

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Report nr. 79 date: 2006, October 27

Abstract
This technical report describes the software for the control and data acquisition (C+DAQ s/w) of the Eclipse K-corona Polarimeter (E-Kpol) instrument. The E-KPol comprises a telescope for imaging of the solar corona during eclipses, a polarimeter for measuring the linear polarization of the K-corona brightness (pB) and a PixelVision camera with back-illuminated CCD. The polarimeter uses a Liquid Crystal Variable Retarders (LCVRs) for polarization modulation. Birifrangence changes with different voltages applied to the LCVR through the Meadolwlark (MLO) D2040 digital controller. The C+DAQ s/w allows to operate the MLO D2040 and the PixelVision CCD camera in interactive and sequential mode.

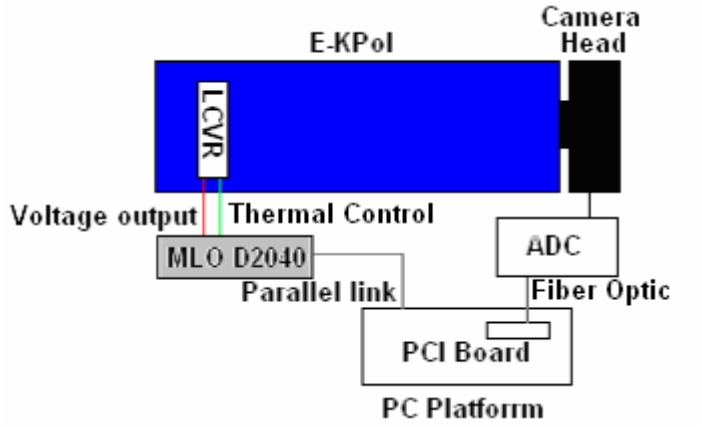


Figure 0 - *Block diagram of the E-KPol components controlled by the C+DAQ s/w*

LCVR Control

Voltages are applied to the LCVR by MLO D2040 digital controller. The controller is programmable through parallel port and has 2 outputs: Voltage and Thermal outputs. *Voltage output* is a BNC type output and *temperature output* is a 5 pin type output. Voltage output sets the LCVR voltage. Temperature output reads and sets its temperature. Voltage output is a square wave width 2kHz frequency and ± V_{set} amplitude. If there is no signal input, the voltage output is a 40Vp-p amplitude wave (Fig. 1).

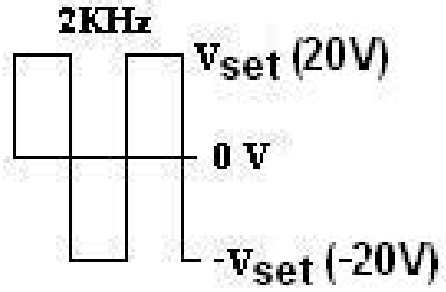


Figure 1 –*MLO D2040 voltage output*

Data sheet is reported in Appendix A1.

CCD Control
Data Acquisition is realized by Spectra Video CCD camera, manufactured by Pixel Vision Inc. Signal and data are transferred to PC by optical fibre. Specifications are the follows:

CCD Pixels: 1024 x 1024
A/D Conversion: 16 bit
Full Well Capacity: 80 000 – 1 200 000 electrons
Readout Amplifier Noise: 4 – 9 electrons / per readout
Readout Rate: 50 – 450 kpix/sec
Row Shift Period: 24 – 60 μsec

Software for Control and Data Acquisition
The software for control and data acquisition (C+DAQ s/w) is realized with LabVIEW, a development tool by National Instruments. The C+DAQ s/w has been developed at the Turin Astronomical Observatory for the E-KPol.
LCVR control commands are "word" received by the MLO D2040 via parallel port. A command library from Pixel Vision (*PVAPI.dll*) has been used for camera control and data acquisition
When the software is launched, the main window shown in Fig. 2 is dispalyed

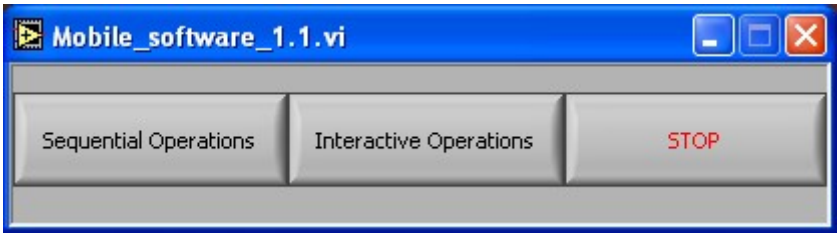


Figure 2 –*Software main window*

The main window allows two different operational modes: **Interactive** or **Sequential**.

Interactive Operations

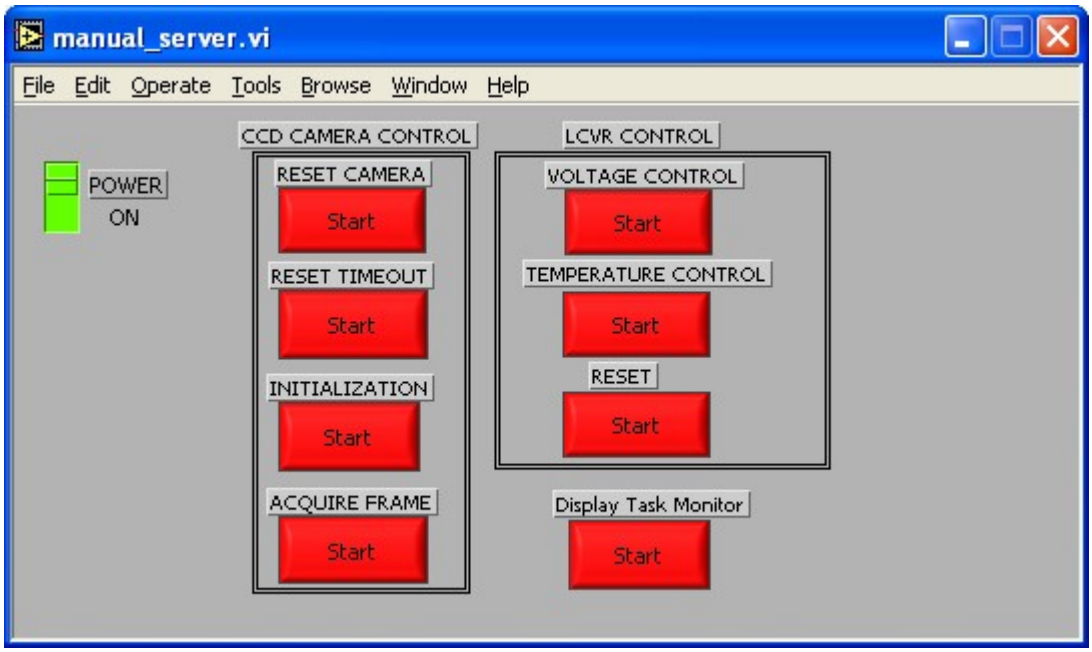


Figure 3 –*Interactive mode main window*

Interactive mode is used for the individual control of the LVCR and the camera. LCVR and camera operations are executable in parallel. Possible operations are:

 # Camera reset

This operation calls the following library function:

int WINAPI pvInitCapture(BYTE *byBoardNum***)**

Parameters:

byBoardNum
The board number to initialize.

Return Value:
SUCCESS or an error code.

This operation is request before first data acquisition.

Figure 4 –*Camera Reset Command Panel*

 # Reset TimeOut

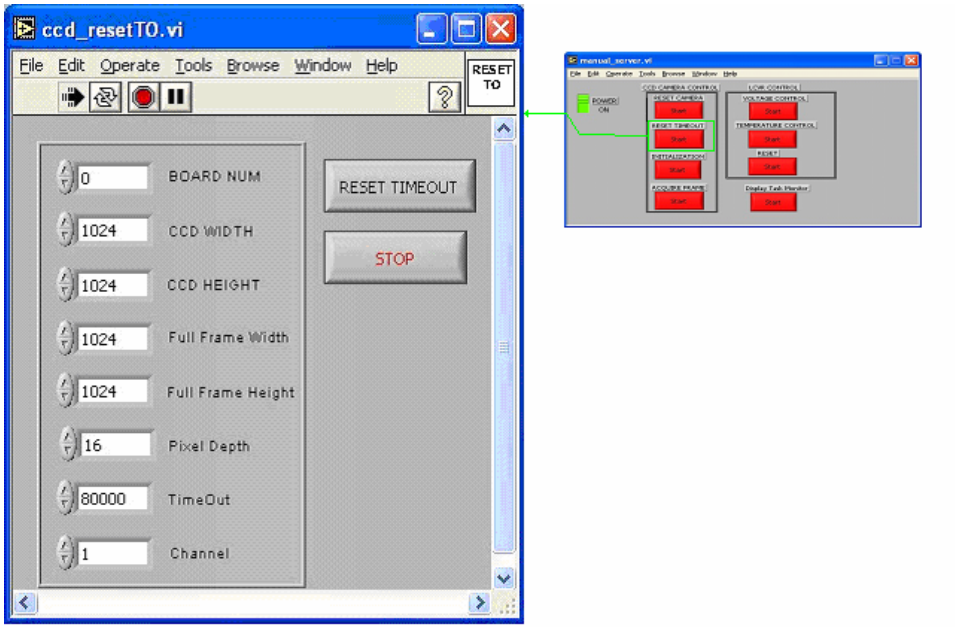


Figure 5 –*Camera Reset TimeOut CommandPanel*

This operation calls the following library function::

int WINAPI pvSetOptions (BYTE *byBoardNum,*
DWORD *dwWidth,,*
DWORD *dwHeight,*
DWORD *dwPixelDepth,*
DWORD *dwTimeOut,*
DWORD *dwChannels***);**

int WINAPI pvSetCCDSize(BYTE *byBoardNum*
int *nWidth,*
int *nHeight);*

pvSetOptions sets the parameters used in capturing a frame of data from the board *BoardNumber*.

pvSetCCDSize sets the values the PVAPI DLL used to calculate the CCD window size.

Parameters pvSetOptions:

byBoardNum
The board used.

dwWidth
Width of a full frame.

dwHeight
Height of a full frame.

dwPixelDepth
The number of bits per pixel on this board.

dwTimeOut
Number of milliseconds to wait before assuming the board has failed to correctly capture the frame. If **pvSetExposureMode** is called after this function, this timeout will be extended by the exposure time.

dwChannels
Number of channels to capture - Valid number of channels to capture are 1, 2 and 4.

Return Value:
SUCCESS or an error code.

Parameters pvSetCCDSize:

byBoardNum
The number of the board receiving this command.

nWidth
The new width of the CCD.

nHeight

The new height of the CCD.

Return value:

SUCCESS or an error code.

 # Initialization

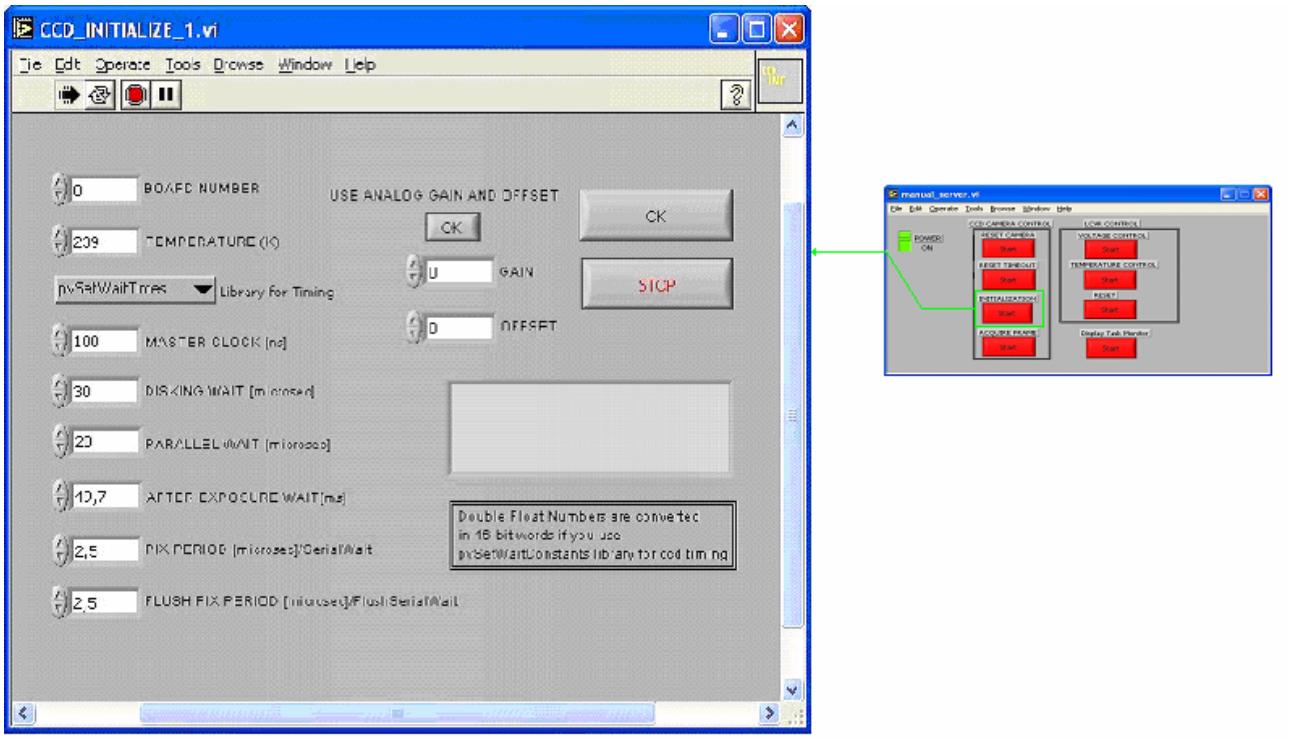


Figure 6 –*Camera Initialization*

This operation calls the following library function:

int WINAPI pvSetCCDTemperatureCalibrated(BYTE *byBoardNum,*
double *dTemp);*

int WINAPI pvSetWaitConstants(BYTE *byBoardNum*
WORD *wMasterClock,*
WORD *wDiskingWait,*
WORD *wParallelWait,*
WORD *wAfterExposureWait,*
WORD *wSerialWait,*
WORD *wFlushSerialWait***);**

int WINAPI pvSetAnalogGainAndOffset(BYTE *byBoardNum,*
BYTE *byChannel,*
WORD *wGain,*
WORD *wOffset***);**

In alternative to **pvSetWaitConstants,** it's possible to use the following library:

int WINAPI pvSetWaitTimes(BYTE *byBoardNum*
double *dMasterClock,*
double *dDiskingWait,*
double *dParallelWait,*
double *dAfterExposureWait,*
double *dPixPeriod,*
double *dFlushPixPeriod***);**

pvSetCCDTemperatureCalibrated sends the command to set the target temperature for the CCD. The CCD will not be at this temperature immediately when this function is called. This function merely sets the target temperature for the thermo-electric cooler in the camera unit. The time it takes the CCD to reach the given temperature will vary depending upon the difference between the target temperature and the current temperature. Also, depending on the ambient temperature, it may not be possible to reach the target temperature at all. Generally, the thermo-electric cooler is able to cool the CCD to 45 to 50° C below the ambient temperature.

The temperature passed to this function should be in Kelvin. The function will then use the TempGain and TempOffset values stored in the PixelView section of your registry file to calculate the raw temperature constant.

pvSetWaitConstants allows you to set the various timing constants used by the control unit during flush, exposure and readout.

pvSetAnalogGainAndOffset sets gain and offset modifiers for incoming data on a channel by channel basis. Changing these values modifies the way in which analog data is converted to digital data based on the following formula:

Value = wGain * (BaseValue + wOffset)

Not all cameras support this command. If your camera does not support analog gain and offset, this function will fail.

pvSetWaitTimes allows you to set the various timing constants used by the control unit during flush, exposure and readout. This function is the same as **pvSetWaitConstants** except for the units involved in the parameters. Internally, this function converts to the units expected by **pvSetWaitConstants** and calls that function. Therefore, **pvSetWaitConstants** is the preferred form.

Parameters pvSetCCDTemperatureCalibrated:

byBoardNum
The number of the board to receive this command.

dTemp
The target temperature expressed in Kelvin.

Return value:
SUCCESS or an error code.

Parameters pvSetWaitConstants:

byBoardNum

The number of the board receiving this command.

wMasterClock

The speed of the DSP master clock. This number is stored in the registry as:

HKEY_LOCAL_MACHINE\Software\PixelVision\PixelView\3.2\Board *n*\CCD Default Setup\Master Clock

wDiskingWait

Time to wait after parallel shift but before serial shift. This wait provides time to move a line of pixels from the board memory into user memory. This number is stored in the registry as:

HKEY_LOCAL_MACHINE\Software\PixelVision\PixelView\3.2\Board *n*\CCD Default Setup\Disking Wait

wParallelWait

The time of each parallel state (overlap time). This number is stored in the registry as:

HKEY_LOCAL_MACHINE\Software\PixelVision\PixelView\3.2\Board *n*\CCD Default Setup\Parallel Wait

wAfterExposureWait

Time to wait after exposure but before readout. This wait allows time for the shutter to close, phosphor to decay, etc. This number is stored in the registry as:

HKEY_LOCAL_MACHINE\Software\PixelVision\PixelView\3.2\Board *n*\CCD Default Setup\After Exposure Wait

wSerialWait

This number is used to calculate the pixel period. This number is stored in the registry as:

HKEY_LOCAL_MACHINE\Software\PixelVision\PixelView\3.2\Board *n*\CCD Default Setup\Serial Wait

wFlushSerialWait

This number is used to calculate the flush-mode pixel period. This number is stored in the registry as:

HKEY_LOCAL_MACHINE\Software\PixelVision\PixelView\3.2\Board *n*\CCD Default Setup\Skip Wait Count

Return value:

SUCCESS or an error code.

Parameters pvSetAnalogGainAndOffsets:

byBoardNum

The number of the board for which the gain and offset are being changed.

byChannel

The channel for which the gain and offset are being changed.

wGain

The new gain modifier. This should be a value in the range 0 to 4095.

wOffset

The new offset modifier. This should be a value in the range 0 to 4095.

Return value:
SUCCESS or an error code.

Parameters pvSetWaitTimes:

byBoardNum
The number of the board to receive this command.

dMasterClock
This is the speed of the DSP's maser clock in nanoseconds.

dDiskingWait
Time to wait after parallel shift but before serial shift, in microseconds. This wait provides time to move a line of pixels from the board memory into user memory.

dParallelWait
The time of each parallel state (overlap time), in microseconds.

dAfterExposureWait
Time to wait after exposure but before readout, in milliseconds. This wait allows time for the shutter to close, phosphor to decay, etc.

dPixPeriod
This wait represents the time needed to move one pixel from the CCD into the readout buffer. This number is in microseconds.

dFlushPixPeriod
This wait represents the time needed to move one pixel from the CCD during non-readout time (flush). This number is in microseconds.

Return value:
SUCCESS or an error code.

 # Acquire Frame

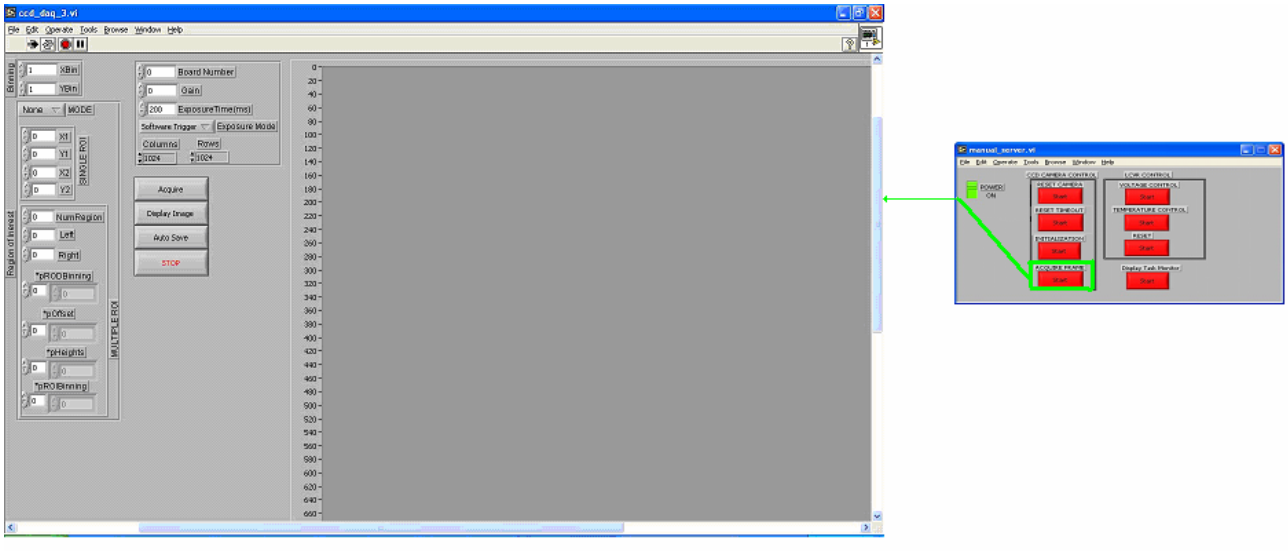


Figure 7 –*Acquire Frame panel*

This operation calls the following this library function::

int WINAPI pvSetPROMPage(BYTE *byBoardNum,*
int *nPage);*

int WINAPI pvSetXBinning(BYTE *byBoardNum,*
WORD *wPixelsBinned***);**

int WINAPI pvSetYBinning(BYTE *byBoardNum*
WORD *wPixelsBinned***);**

int WINAPI pvDisableROI (BYTE *byBoardNum***);**
or

int WINAPI pvEnableSingleROI(BYTE *byBoardNum*
WORD *wX1,*
WORD *wY1,*
WORD *wX2,*
WORD *wY2***);**

or

int WINAPI pvEnableMultipleROI(BYTE *byBoardNum*
WORD *wNumRegions,*
WORD *wLeft,*
WORD *wRight,*
WORD **pOffsets,*
WORD **pHeights,*
WORD **pROIBinning,*
WORD **pRODBinning);*

int WINAPI pvSetExposureMode(BYTE *byBoardNum,*
UINT *nExposureMode,*
double *dExposureTime);*

pvSetPROMPage loads a new DSP code page. This functions is used to select the gain and output.

pvSetXBinning sets the number of pixels that are grouped together during readout.

pvSetYBinning sets the number of pixels that are grouped together during readout.

pvDisableROI sends the command to disable region of interest processing. This command does not apply to frames that have already been acquired.

pvEnableSingleROI sets up a single region of interest.

pvEnableMultipleROI enables you to set up to 8 regions of interest as well as the bin setting for each ROI and ROD.

pvSetExposureMode sends the command to set the exposure timing mode and, if necessary, the exposure time. Actual exposure time will be approximately equal to the value passed in but is set in increments of pixel periods (typically several microseconds) so the actual exposure time may vary slightly.

Parameters SetPROMPage:

byBoardNum
The number of the board to receive this command.

nPage
The number of the PROM page to be loaded. This value can be 0 through 7 or one of the pre-defined constants PV_HI_GAIN or PV_LO_GAIN. If one of the pre-defined constants is used, the page number is read from the registry. Otherwise, this value will be treated as an absolute.

Return value:
SUCCESS or an error code.

Parameters SetXBinning:

byBoardNum
The number of the board to receive this command.

wPixelsBinned
The number of pixels to group together.

Return value:
SUCCESS or an error code.

Parameters SetYBinning:

byBoardNum
The number of the board to receive this command.

wPixelsBinned
The number of pixels to group together.

Return value:
SUCCESS or an error code.

Parameters pvDisableROI:

byBoardNum
The board which is to receive the command.

Return Value:
SUCCESS or an error code.

Parameters pvEnableSingleROI:

byBoardNum
The number of the board to receive this command.

wX1
Sets the x-coordinate of the left side of the ROI.

wY1
Sets the y-coordinate of the top of the ROI.

wX2
Sets the x-coordinate of the right side of the ROI.

wY2
Sets the y-coordinate of the bottom of the ROI.

Return value:
SUCCESS or an error code.

Parameters pvEnableMultipleROI:

byBoardNum
The number of the board to receive this command.

wNumRegions
The number of regions of interest to be set.

wLeft
The offset of the left side of the regions, in pixels.

wRight

The offset of the right side of the regions, in pixels.

pOffsets

An array of values specifying the offset from the top of the CCD of each ROI, in Pixels. The number of elements in this list must equal *wNumRegions*. NOTE: Element zero is not used.

pHeights

An array of values specifying the height of each ROI, in Pixels. The number of elements in this list must equal *wNumRegions*. NOTE: Element zero is used to set the ROD before all of the ROIs and can be zero if no beginning ROD is desired

pROIBinning

An array of values specifying the binning of each ROI, in Lines. The number of elements in this list must equal *wNumRegions*. NOTE: Element zero is not used.

pRODBinning

An array of values specifying the binning of each ROD, in Lines. The number of elements in this list must equal *wNumRegions*. NOTE: Element zero is used to set the binning for the ROD before the ROIs.

Return value:

SUCCESS or an error code.

Parameters pvSetExposureMode:

byBoardNum

The number of the board to receive this command.

nExposureMode

A constant identifying the intended exposure mode. Possible values are PV_XM_EXT_TRIGGER (0), PV_XM_SOFT_TRIGGER (1), PV_XM_INT_TRIGGER (2) and PV_XM_EXT_GATE (3). PV_XM_EXT_TRIGGER and PV_XM_EXT_GATE may also be combined with PV_XM_DELAYED_ENABLE to prevent external triggers from being accepted before the software is ready.

dExposureTime

The desired exposure time in seconds. If *nExposureMode* is PV_XM_EXT_GATE, this parameter is ignored.

Return value:

SUCCESS or an error code.

In this subroutine, the current frame is acquired. User can select options for image display and auto-save.
Data are saved in FITS standard format.

N.B: Before to save data in FITS standard format, data are converted in vector format.

 # LCVR Voltage Control

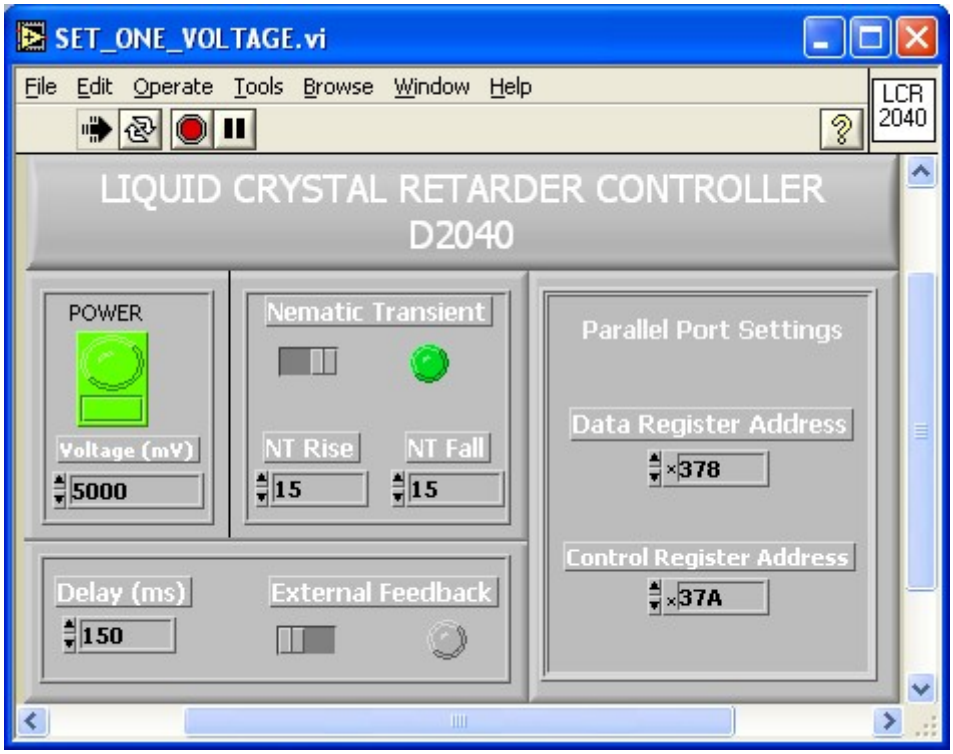


Figure 8 – *Set LCVR Voltage panel*

Settable parameters are:
- Parallel Port Address;
- Delay between word sended;
- Transient Nematic Effect parameters;
- Voltage;
- Options External Feedback (set voltage equal to 10 V).

 # LCVR Temperature Control

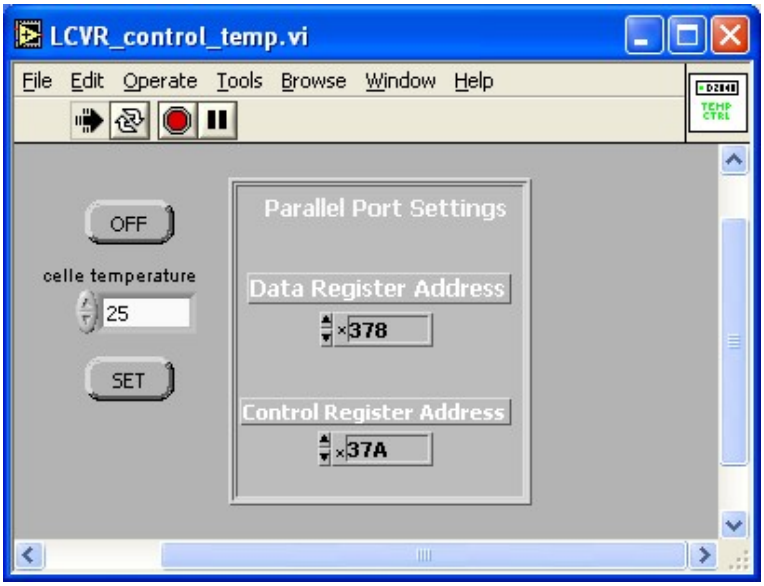


Figure 9 – *Set LCVR Temperature panel*

Settable parameters are:
- Parallel Port Address;
- Temperature.

 # Reset LCVR

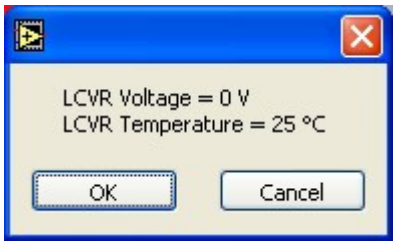


Figure 10 – *Reset LCVR window*

This options set LCVR voltage to 0 V and temperature to 25°C.

 # Display Task Monitor
This function display memory usage, processor usage and active processes.

Sequential Operations

Sequential acquisition requires a configuration file , and an “obseq” file. Examples of the structure of these files are given in the following:

Configuration_file.dat

```
//_____________________________________________
//Configuration file for ccd-lcvr software
//Realized by G. Capobianco for OATo
//Date: 2006-1-15
//_____________________________________________

//Parameters for D2040

//Transient Nematic Effect
TNE=T; //Possibles values are T or F
NT_Rise=15;
NT_Fall=15;

//Delay [ms]
delay=150;

//Parallel Port Settings
Data_Register_Address=378;
Control_Register_Address=37A;

//Temperature[°C]
LCVR_Temp=30;


//Parameters for PixelVision-SpectraVideo camera
```

```
//BoardNum is request in all functions
  BoardNum=0; //Possibles values are 0 or 1

//pvSetOptions parameters
  Timeout(ms)=8000;
  Channels=1; //Possibles value are 1,2,3,4 or 8

  //please, don't modify this values.
  //_____________________________

  FullFrameWidth=1024;
  FullFrameHeight=1024;
  PixelDepth=16;

  //_____________________________

//pvSetCCDSize
  CCDWidth=1024;
  CCDHeight=1024;

//pvSetPromPage
  Gain=4;

//pvSetCCDTemperature
  CCDTemperature(K)=235;
  //Minimun temperature value is approx 235K

//pvSetWaitConstants
//TIMING--TIMING--TIMING--
  MasterClock=100;
  DiskingWait=70;
  ParallelWait=50;
  AfterExposureWait=150;
  SerialWait=20;
  FlushSerialWait=20;

//pvSetBinning

//pvSetRoi

//pvSetAnalogGainandOffsets
  Use = F; //Possibles value are T or F if you use or you don't use analog gain and offsets
  gain=65535;
  offset=65535;
  channels=1;

//pvSetExposureMode
  ExposureMode=1;
  //0=External Trigger, 1=Software Trigger;
  //2=Internal Trigger; 3=External Gate
```

//ExposureTime
//columns=1024;
//rows=1024;

//Dati osservativi
Origin=OAVDA; //Insitute where data are originated
Latitude=; //Observatory Latitude
Longitude=; //Observatory Longitude
Observer=G.Capobianco;

Obseq.dat

//_____
//Setting file for sequential acquisition
//Author: G. Capobianco
//Date: 2006-01-26
//_____

//Voltages for LCVR [mV]
V=0,1000,2000,5000;

//Exposition Time [ms]
T=100,200,400,200,100;

//ROI Mode 0=None;1=Single

ROI=0,0,0,0,0;

//If Single ROI
X1=0,0,0,0,0;
Y1=0,0,0,0,0;
X2=0,0,500,0,0;
Y2=0,0,500,0,0;

//BIN

XBin=1,1,1,1,1;
YBin=1,1,1,1,1;

C+DAQ sets parameters specified in configuration file and then, for every LCVR voltage (vector V write in obseq file) acquire images with camera parameters specified in obseq file.Images are automatically saved. Status of daq process is displayed in automatic acquisition home page.

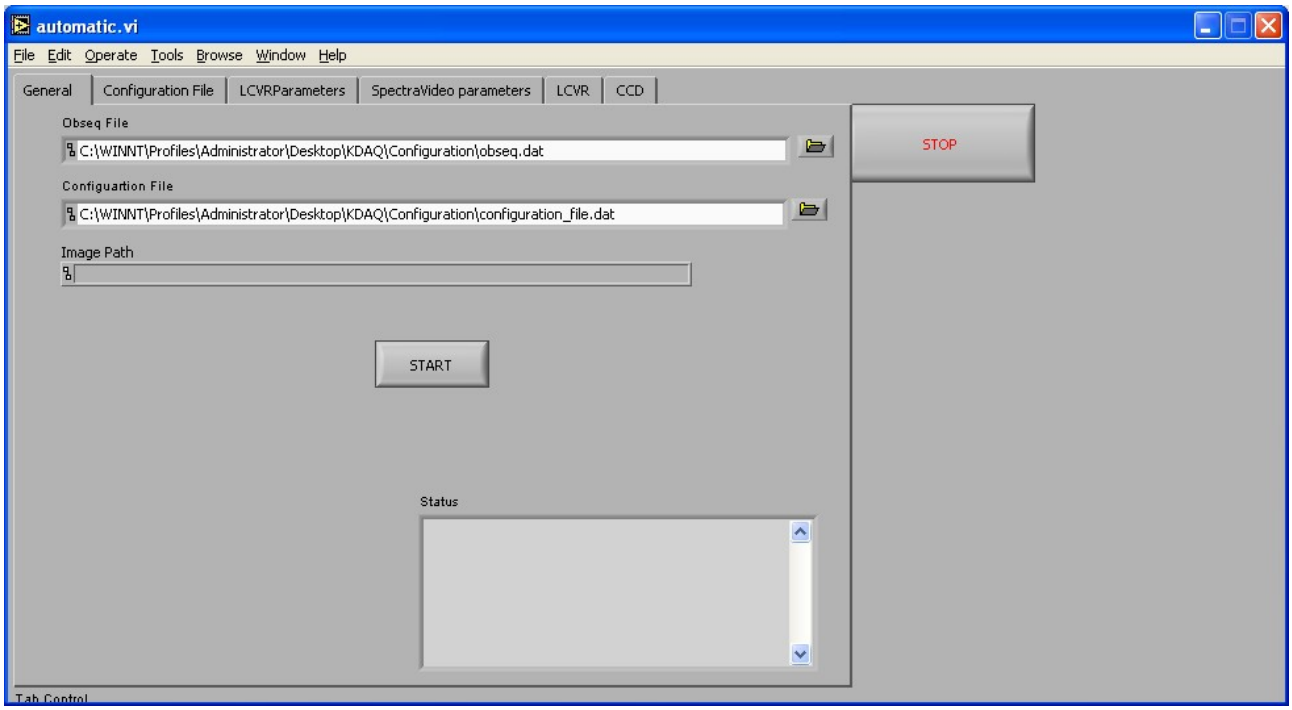
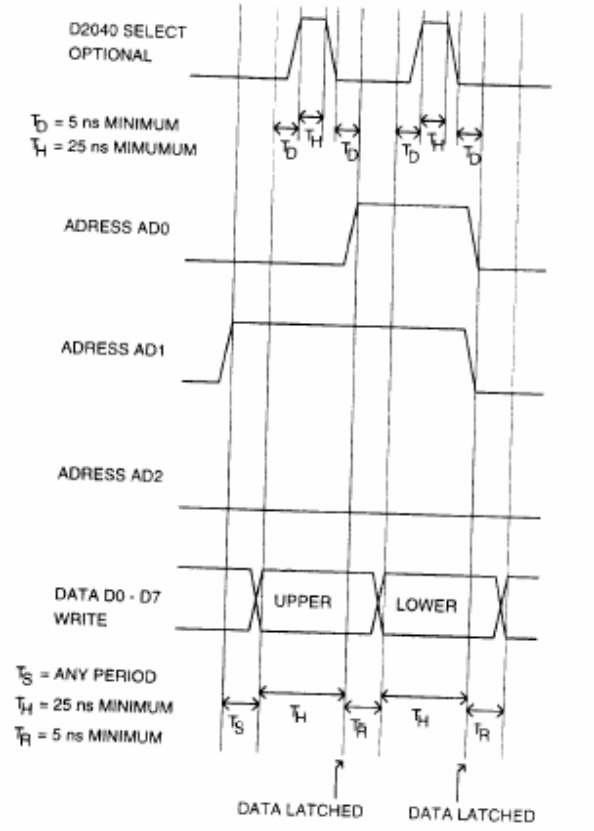


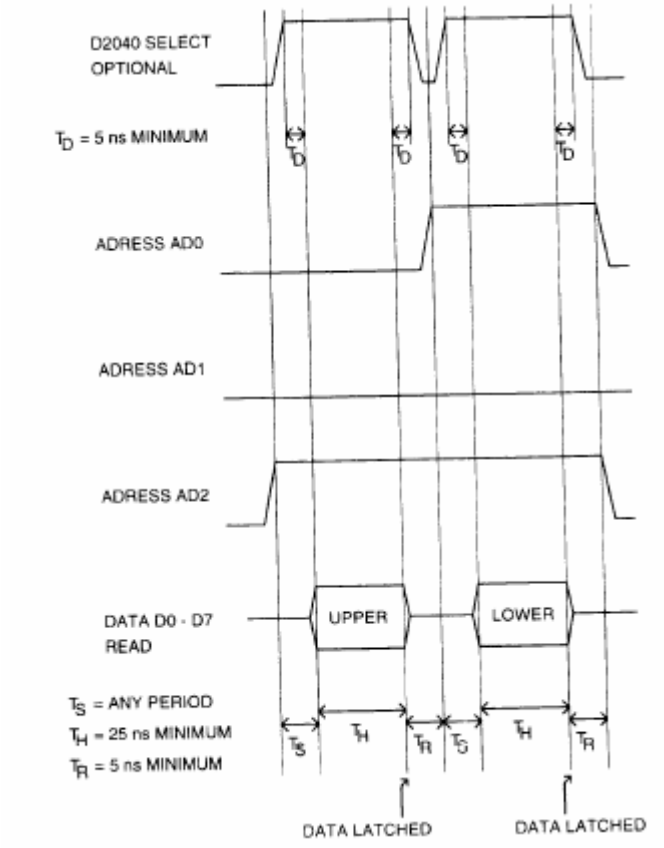
Figure 11 – *Automatic Acquisition window*

APPENDIX A – MLO D2040 Data Sheets

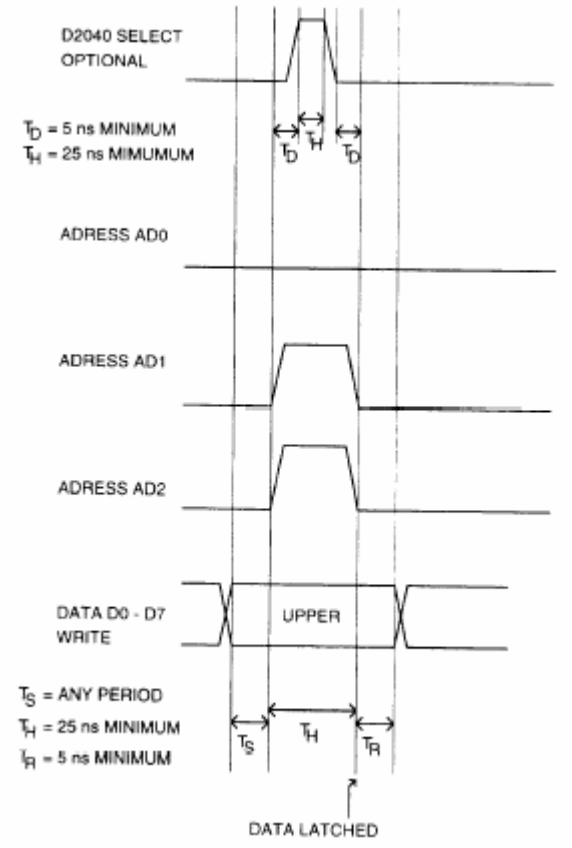
Timing diagram for the D2O4O LC Output. A Write cvcle.



Timing diagram for the D2040 Temperature Sensing. A Read cycle.



Timing diagram for the D2040 Temperature Sensing. A Write cycle.



D2040 Technical Specifications

LC Output Voltage (standard D2040)	2KHz AC Square wave (50.0% duty cycle) adjustable from 0 to 20 Volts peak (40 V peak to peak)
LC Output resolution	0.61 mVpeak increments 0-20.000 Vpeak
LC Output Maximum load	20 ma.
LC Output slew rate	11.5V/μs (transition rate between plus and minus peak voltage values)
LC Output D.C. bias	± 5mV D.C. Maximum
Digital Input (standard D2040)	8 bit data path, 3 control inputs (TTL level logic)
Digital Input (with options)	3 additional control inputs (TTL level logic)
Digital Outputs	2 sync outputs (one inverted) (TTL level logic)
Temperature Sense range	1.0°C to 100.0°C
Temperature Sense accuracy	±0.5°C
Temperature Control Range	ambient to 100.0°C
Temperature Sense accuracy	±1.0°C
5 volt Power Supply Output	5 Volt +/- 5%, 100 ma maximum
Operating environment	0°C to 50°C
Storage environment	-55°C to 100°C
Weight	3.85 lbs (1.75 kg)
Power requirements	Line voltage 115vac ±10% 50/60Hz or 230vac ±10% 50/60Hz
Power consumption	8 watts without heater control 18 watts with heater control