DXP - EPICS software for XIA Digital Signal Processing System

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Overview

The EPICS DXP module provides support for the digital signal processor based multichannel analyzers from X-ray Instrumentation Associates (XIA). These devices all contain the functional equivalent of the shaping amplifier, ADC, and MCA of a conventional pulse-height analysis system. The term "DXP" in this document stands for Digital X-ray Processor, and refers to all models of the XIA hardware.

DXP supports the following hardware:

- The xMAP, which is a 4-channel PXI card. The PXI crate is typically connected to a Windows PC with a PCI/PXI fiber-optic bridge, but can also be controlled by a CPU processor card in the PXI crate itself.
- The Mercury (single channel) and Mercury4 (4 channel) standalone desktop units that communicate over the USB 2.0 port. They both have similar mapping features to the xMAP. Where the term Mercury is used in this document it applies to both the Mercury and Mercury4 unless otherwise stated.
- The Saturn, which is a standalone desktop unit that communicates over the PC Enhanced Parallel Port (EPP) or USB port. The Vortex detector from SII (formerly Radiant) is an OEM version of the Saturn, and it also works with this software.
- The DXP2X, which is a single-width CAMAC module. Each module contains 2 or 4 channels with similar pulse-processing electronics to the Saturn.

DXP currently supports this hardware under the following operating systems and interfaces:

- The xMAP with the EPICS IOC running on Windows, using the National Instruments PCI/PXI adapter, or with a CPU card running Windows directly in the PXI crate.
- The Mercury with the EPICS IOC running on Windows or Linux using the USB 2.0 interface.
- The Saturn with the EPICS IOC running on Windows or Linux, using the EPP parallel port, USB 1.0, or USB 2.0 interfaces.
- The DXP2X with the EPICS IOC running on vxWorks, using the Kinetic Systems 2917/3922 VME to CAMAC interface. Other CAMAC interfaces that have software support for the ESONE standard CAMAC library calls should also work, but have not been tested.

On Windows both the EPICS win32-x86 (Microsoft VC++ compiler) and cygwin-x86 (gcc compiler) architectures are supported.

The features of the EPICS software, compared with software available from XIA are:

- Control and data acquisition are available over the network, from any application or language that supports the EPICS Channel Access protocol (based on TCP/IP). This means that EPICS clients written in languages like Python, IDL, LabView, Visual Basic, etc. can control the DXP modules and read the data. These applications can be running on any computer on the Internet, they do not need to run on the computer that is attached to the XIA hardware. This client/server model is very desirable in complex data acquisition environments, such as synchrotron beamlines, because it allows the DXP control and data acquisition to be integrated with other hardware and software. For example, a control software program can move a motor, command the DXP to acquire data, and write the data to disk.
- A single software package supports the xMAP, Mercury, Saturn, and DXP2X.
- The Saturn and Mercury can be run from Windows and Linux, while the XIA control programs only run on Windows.
- The DXP2X support uses the standard XIA Handel library, while the XIA MESA package uses an old LabView interface.

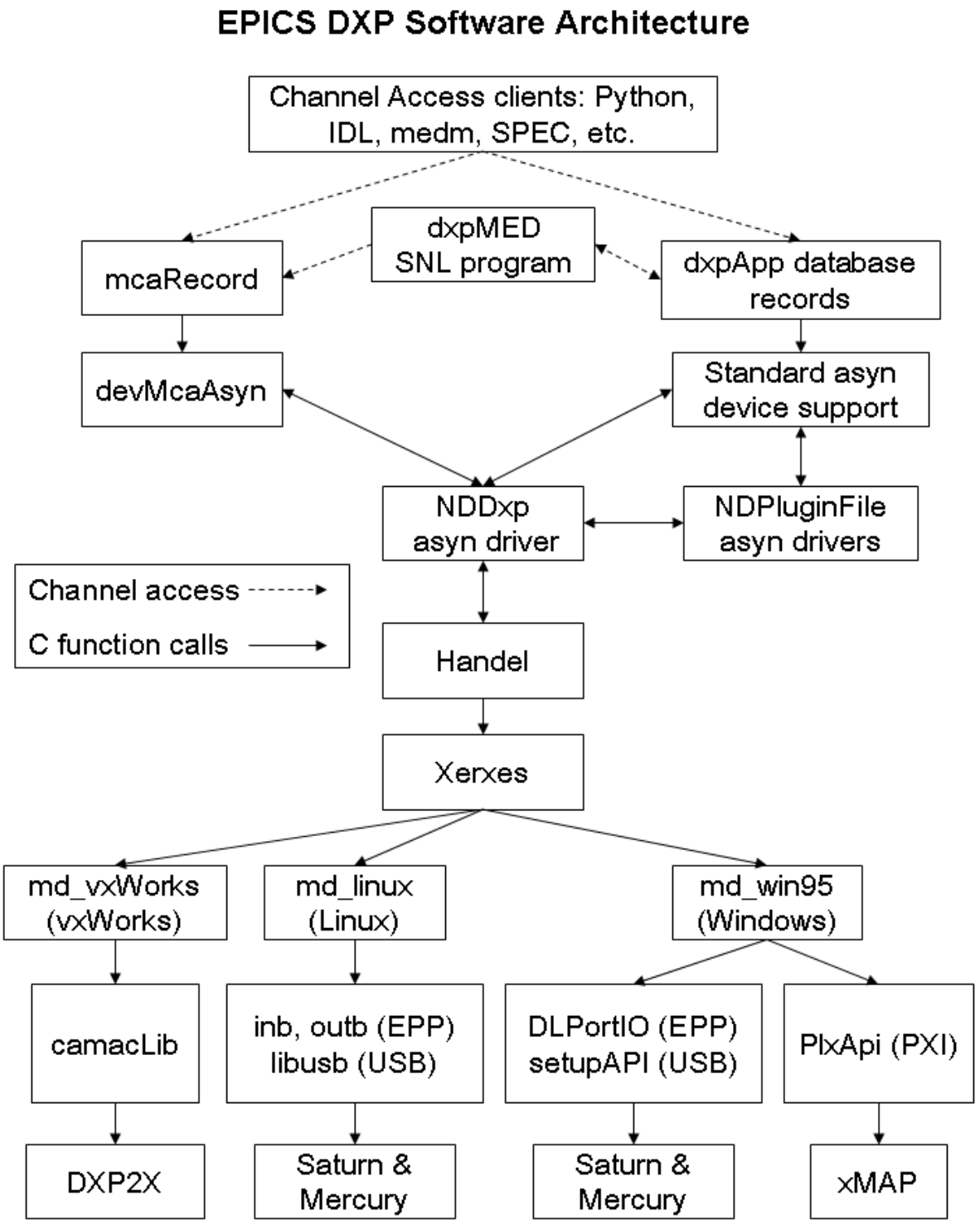
Architecture

The software consists of the following components:

- An asyn port driver. This driver is implements a class called NDDxp, which is derived from the asynNDArrayDriver and asynPortDriver base C++ classes. The driver communicates with the hardware using the XIA Handel library, which in turn communicates with the XIA Xerxes library.
- An EPICS MCA record for each detector. This communicates with the driver via the asyn MCA device support. This support allows each detector to be treated identically with other supported MCA hardware,

such as the Canberra AIM. The MCA record is used for data acquisition in the non-mapping modes, and to define regions of interest.
- A set of standard EPICS records (ai, ao, bi, bo, waveform, etc.) that are used to set all of the many software selectable parameters for the DXP, including peaking times, pileup rejection criteria, etc. These are also used for data acquisition in the mapping modes and to acquire diagnostic data, such as the baseline histogram and ADC trace. These records use the standard asyn device support.
- A State Notation Language program (dxpMED) for synchronizing acquisition, ROIs, and DXP parameters in multi-element detector systems.
- Support for the file-saving plugins from the areaDetector package. These plugins are used to stream data to disk in the mappping modes on the xMAP and Mercury.
- Databases for single-element and multi-element detector systems.
- medm display screens for single-element and multi-element detector systems.
- Example IOC boot directories for the Saturn and Mercury on Windows and Linux, for the xMAP on Windows, and for the DXP2X on vxWorks.

The overall architecture of the EPICS DXP software is shown in the diagram below. At the top level are EPICS Channel Access client applications, such as the IDL MCA Display program, the IDL Multi-Element Detector (MED) Display program, medm, spec, and others.



EPICS Records and Databases

This document does not attempt to explain the meaning or use of all of the DXP parameters. The best

documentation of the operation of the DXP modules is provided by XIA in the xMAP User's Manual, Mercury User's Manual, and the Saturn User's Manual. These manuals all provide an excellent description of the theory of digital pulse processing as implemented in the DXP models from XIA. They also describe the XIA xManager and ProSpect software, which can be useful in setting up and testing the hardware, but which do not apply when running the EPICS software. The xMAP and Mercury manuals also explain the mapping modes that these models support.

For many parameters in the following databases there is both an EPICS output record (ao, bo, mbbo, etc.) and a corresponding EPICS input record (ai, bi, mbbi, etc.). The output record is used to set a new value in the DXP hardware. The input record has an _RBV suffix, which stands for Read Back Value. It is used to read back the actual value from the hardware, which may be different from the requested value because of limitations of the hardware, errors, etc.

When the EPICS IOC starts the initial values of the records are set in the following order:

1. The default value in the record definition, typically 0.
2. The value specified in the database file (.template or .substitutions file)
3. The value read back from the hardware or Handel library. This will be the Handel default value, or the value from the .ini file if it is defined there.
4. The value from save/restore.
5. The value from a "dbpf" in the startup script.
6. The value set from the SNL program on startup.

Steps 1-3 apply to both output records and to input records. Steps 4 and 5 typically only apply to output records, and step 7 only to input records. If there is no auto_settings*.sav file then most of the DXP parameter records will obtain their initial values from the .ini file. Thus, by deleting the auto_settings*.sav file one can force EPICS to use the same parameters that have been saved into an .ini file, for example by xManager or ProSpect.

dxpHighLevel.template

The following records are defined in the database dxpHighLevel.template. They control the high-level DXP parameters such as peaking time, etc. One instance of this database is loaded for each detector channel in the system. All of the record names in the template file are preceeded by the macro parameters (P)(R), where $(P) is the prefix for this detector system, and $(R) is the name of this specific channel. $(P) should be unique for all EPICS IOCs on the subnet, and $(R) is typically dxp1:, dxp2:, etc.

Records in dxpHighLevel.template		
Record Name	**Record Type**	**Description**
Trigger Filter Records		
TriggerPeakingTime TriggerPeakingTime_RBV	ao ai	The peaking time in microseconds for the trigger (fast) filter. The trigger filter is used to detect input pulses.
TriggerGapTime TriggerGapTime_RBV	ao ai	The gap time in microseconds for the fast filter. This gap time is generally set to 0.
TriggerThreshold TriggerThreshold_RBV	ao ai	The threshold in keV for the trigger filter.

Energy Filter Records		
PeakingTime PeakingTime_RBV	ao ai	The peaking time in microseconds for the energy (slow) filter. The energy filter is used to measure the energy of the input pulses. Increasing this time will generally improve the energy resolution at the expense of decreased throughput.
GapTime GapTime_RBV	ao ai	The gap time in microseconds for the energy filter. The gap time is set to reflect the rise time of the input signal.
EnergyThreshold EnergyThreshold_RBV	ao ai	The threshold in keV for the energy filter. This should generally be set to 0 except for soft x-ray spectroscopy.
MaxWidth MaxWidth_RBV	ao ai	Maximum peak width in microseconds for pileup inspection.
Baseline Records		
BaselineFilterLength BaselineFilterLength_RBV	mbbo longin	The length of the baseline filter in samples. Menu values are powers of 2 from 8 to 2048.
BaselineThreshold BaselineThreshold_RBV	ao ai	The threshold in keV for the baseline filter.
BaselineCutPercent BaselineCutPercent_RBV	ao ai	The baseline cut value, in percent units of the baseline histogram. Baseline values outside the cut range will not be used in computing the baseline average, but they will still be included in the baseline histogram. *Note: this parameter only applies to the Saturn and DXP2X, it is not used on the xMAP or Mercury.*
BaselineCutEnable BaselineCutEnable_RBV	bo bi	A flag to enable or disable the baseline cut. *Note: this parameter only applies to the Saturn and DXP2X, it is not used on the xMAP or Mercury.*
Pre-amp and Energy Range Records		
PreampGain PreampGain_RBV	ao ai	The gain of the detector pre-amp in mV/keV. Setting this value accurately is important, because it allows the DXP software to be correctly internally calibrated. PreampGain should be adjusted so that the requested MaxEnergy value agrees with the actual energy of the last MCA channel.
DetectorPolarity DetectorPolarity_RBV	bo bi	Pre-amp polarity (not high-voltage polarity). 0=Negative, 1=Positive. Positive polarity means an x-ray pulse causes an increase in the pre-amp voltage output. This is normally defined in the .ini file, but is accessible to EPICS to allow quick determination of the correct polarity.
ResetDelay ResetDelay_RBV	ao ai	For reset pre-amps the time in microseconds to recover after a pre-amp reset. *Note: older xMAPs (before revision D) should use 10 microseconds, newer xMAPs (revision D and later) can use 1 microsecond.*
DecayTime DecayTime_RBV	ao ai	For RC pre-amps the characteristic decay time in microseconds.

MaxEnergy MaxEnergy_RBV	ao ai	The energy of the last channel in the spectrum in keV. If the actual energy of the last channel, determined by performing an MCA energy calibration, is not equal to this value, then one should modify the value of PrempGain.
MCABinWidth_RBV	ai	The width of each bin in the MCA spectrum in keV. This is computed from PreampGain, MaxEnergy, and the NUSE field of the MCA record.
ADCPercentRule ADCPercentRule_RBV	ao ai	The percent of the range of the input ADC that should be used for pulses whose energy is at the energy of the CalibrationEnergy, which the driver automatically sets to be MaxEnergy/2, i.e. the middle channel of the spectrum. The normal range is 3-10% for reset pre-amplifiers and 30-50% for RC pre-amplifiers. The goal is to digitize the baseline noise into a few ADC bits (look at the ADC trace), but not have the value so large that the input signal drifts out of the ADC range too often (look at the number of drift ups and drift downs, NUMDRUPS0 and NUMDRDOS0).
CalibrationEnergy_RBV	ai	The energy at which the ADCPercentRule applies. The EPICS driver automatically sets this to MaxEnergy/2.
DynamicRange_RBV	ai	The dynamic range of the ADC. This is computed from PreampGain, MaxEnergy, and ADCPercentRule.
Preset Counting Records		
PresetMode PresetMode_RBV	mbbo mbbi	The preset counting mode. On the xMAP and Mercury the choices are: • "No preset" Count until acquisition is stopped manually. • "Real time" Count for a preset real time. The real time is set by the PRTM field of the corresponding MCA record. • "Live time" Count for a preset live time. The live time is set by the PLTM field of the corresponding MCA record. • "Events" The preset number of events is set by the PresetEvents record. • "Triggers" The preset number of triggers is set by the PresetTriggers record. On the Saturn and the DXP2X only the first 3 choices are available; "Events" and "Triggers" are not supported. The preset real time and preset live time are controlled by the .PRTM and .PLTM fields of the corresponding MCA record.
PresetEvents PresetEvents_RBV	longout longin	The number of events to count for. Events are x-rays that were processed by the energy filter, and includes underflow and overflow events that are not actually present in the spectrum.
PresetTriggers PresetTriggers_RBV	longout longin	The number of triggers to count for. Triggers are x-rays that were processed by the trigger filter, and includes pileups and other events that are not actually present in the spectrum.
Counting Statistics Records		

ElapsedRealTime	ai	The elapsed real time. This is the same information as in the .ERTM field of the corresponding MCA record.
ElapsedLiveTime	ai	The elapsed live time. This is the same information as in the .ELTM field of the corresponding MCA record.
ElapsedTriggerLiveTime	ai	The elapsed live time for the trigger filter.
Triggers	longin	The number of trigger filter events.
Events	longin	The number of energy filter events.
Underflows	longin	The number of underflow events, which are events that would be in channels less than 0.
Overflows	longin	The number of overflow events, which are events that would be in channels greater than the last channel in the spectrum.
InputCountRate	ai	The input count rate (ICR), which is the same as Triggers/ElapsedTriggerLiveTime.
OutputCountRate	ai	The output count rate (OCR), which is the same as Events/ElapsedRealTime.
Mapping Records (for xMAP and Mercury)		
CurrentPixel	longin	The current pixel in the mapping run in MCA mapping and SCA mapping modes. In List mapping mode this is the number of bytes in the current mapping buffer. This value applies to the entire moduel, not to each channel, so it is only updated for the first channel on the module.
Diagnostic Trace Records		
BaselineHistogram	waveform	The baseline histogram array. The array is read from the hardware when this record is processed. The baseline histogram provides a valuable diagnostic of the electronic noise in the system. It should ideally be a perfect Gaussian, with a FWHM equal to the electronic noise in the baseline. *Note: this record should not be processed while normal data acquisition is in progress or it will slow things down.*
BaselineEnergyArray	waveform	The energy values for the baseline histogram. This array is used to provide a calibrated X-axis when plotting the BaselineHistogram.
TraceMode TraceMode_RBV	mbbo mbbi	The type of diagnostic trace information to return in the TraceData record. On the xMAP and Mercury the choices are: • "ADC" The equivalent of a digital scope trace of the pre-amp input to the module. • "Baseline history" A history of the baseline samples. • "Trigger filter" The output of the digital trigger filter. • "Baseline filter" The output of the digital baseline filter. • "Energy filter" The output of the digital energy filter. • "Baseline samples" The recent baseline samples. • "Energy samples" The recent energy samples.

		On the Saturn and the DXP2X only the first 2 choices are available, "ADC" and "Baseline history".
TraceData	waveform	The diagnostic trace data. The array is read from the hardware when this record is processed. The type of diagnostic trace data to read is selected with TraceMode, and the time per sample is selected with TraceTime. *Note: this record should not be processed while normal data acquisition is in progress or it will slow things down.*
TraceTime TraceTime_RBV	ao ai	The time per sample in microseconds for the TraceData array. The minimum time depends on the hardware type; it is 0.1 microseconds for the 20 MHz Saturn and DXP2X, .05 microseconds for the 40MHz Saturn, and 0.02 microseconds for the xMAP and Mercury.
TraceTimeArray	waveform	The time values for the trace data. This array is used to provide a calibrated X-axis when plotting the TraceData.

dxpSCA_16.template and dxpSCA_32.template

The following records are defined in the databases dxpSCA_16.template and dxpSCA_32.template. They control the 16 (Saturn and DXP2X) or 32 (xMAP and Mercury) single-channel-analyzers (SCAs) for each channel. Each SCA is defined by a low channel and a high channel. In normal MCA Spectra mode the counts in each SCA are computed by the DXP firmware when acquisition completes. This is essentially the same information as in the MCA record ROIs. However, the SCAs are also used in the fast SCA mapping mode on the xMAP. In this mode only the total counts in each SCA are stored at each point in the map. This mode is faster than full spectrum mapping, and also uses much less disk space. The SCA definitions are also used on the Saturn (when it is equipped with the optional SCA mapping hardware and firmware) and Mercury for hardware ROI mapping. The Saturn and Mercury put out a pulse a TTL output line when an x-ray falls within the channel range of that SCA. This allows very fast mapping, since there is no need to read the spectrum at each point in the scan. The Saturn has 16 such TTL output lines, the Mercury has 14 lines, and the Mercury4 has 24 lines (6 per channel). *Note: in normal MCA spectra mode SCAs are permitted to overlap in channels. However in the SCA mapping mode and SCA pulse output mode, the SCA definitions must not overlap. This is because, for performance reasons, each spectrum channel must be assigned to at most one SCA.*

One instance of this database is loaded for each detector channel in the system. All of the record names in the template file are preceeded by the macro parameters (P)(R), where $(P) is the prefix for this detector system, and $(R) is the name of this specific channel.

Records in dxpSCA_16.template and dxpSCA_32.template		
Record Name	**Record Type**	**Description**
SCA$(N)Low SCA$(N)Low_RBV	longout longin	The low channel for SCA $(N). Actual record names are SCA0Low, SCA1Low, etc.
SCA$(N)High SCA$(N)High_RBV	longout longin	The high channel for SCA $(N). Actual record names are SCA0High, SCA1High, etc.
SCA$(N)Counts	longin	The total counts for SCA $(N). Actual record names are SCA0Counts, SCA1Counts, etc.

dxpLowLevel.template

The DXP firmware is actually controlled by a large number of low-level parameters. Each of these parameters is a 16-bit integer. Typically the user will only interact with the high-level parameters described above. But it can sometimes be useful to read or even modify one of these low-level parameters. The EPICS software provides a completely generic interface to these low-level parameters. When the driver initializes it queries the names of all of the low-level parameters, and makes these names available in stringin records. There is a longin record which provides the current value of each parameter, and a longout record which allows the parameter to be modified. Note that all parameters have a corresponding longout record, but some parameters are inherently read-only, so their longout records actually do nothing. The driver currently hardcodes a maximum of 230 low-level parameters, which is more than the number used by any of the existing firmware (224 is the current maximum, for the xMAP reset firmware). If a future firmware version has more parameters than this, then a single constant in the driver will need to be increased, and more records will need to be added to dxpLowLevel.template.

One instance of this database is loaded for each detector channel in the system. All of the record names in the template file are preceeded by the macro parameters (P)(R), where $(P) is the prefix for this detector system, and $(R) is the name of this specific channel.

Records in dxpLowLevel.template		
Record Name	**Record Type**	**Description**
NumLLParams	longin	The actual number of low-level parameters.
ReadLLParams	bo	Writing 1 to this record will read all of the low-level parameters for this channel.
LL$(N)Name	stringin	The firmware name for low-level parameter $(N), N=0 to NumLLParams-1. Actual record names are LL0Name, LL1Name, etc.
LL$(N)Val_RBV	longin	The readback value for low-level parameter $(N), N=0 to NumLLParams-1. Actual record names are LL0Val_RBV, LL1Val_RBV, etc.
LL$(N)Val	longout	The output value for low-level parameter $(N), N=0 to NumLLParams-1. Actual record names are LL0Val, LL1Val, etc.

dxpSystem.template

The following records are defined in the database dxpSystem.template. One instance of this database is loaded for each DXP system, since they control system-wide parameters. This database is loaded for both single-element (e.g. Saturn and Mercury) and multi-element (e.g. DXP2X, xMAP, and Mercury4) systems. All of the record names in the template file are preceeded by the macro parameter $(P), the prefix for this detector system.

Records in dxpSystem.template		
Record Name	**Record Type**	**Description**
MaxSCAs	longin	The maximum number of SCAs that the system supports. The maximum on the Saturn and DXP2X is 16, and on the xMAP and Mercury the maximum is 64.

NumSCAs NumSCAs_RBV	longout longin	The number of SCAs (ROIs) to use. The records for each SCA are defined in the database dxpSCA_16.template and dxpSCA_32.template. While the xMAP and Mercury support 64 SCAs, the dxpMED State Notation Language program only supports 32. This is because its function is to copy ROIs from the MCA records to the SCAs in the DXP hardware, and the MCA record only supports 32 ROIs. Using fewer SCAs reduces the size of the data files in SCA Mapping mode. **Important note:** when acquisition completes EPICS processes the records with the SCA counts (SCA$(N)Counts) if the values have changed. This can be a very large number of records: for example on a 16-element system if NumSCAs is 32 then 512 records must process if the SCA data have changed. This was measured to take about 300ms. If very short acquisition times are being used, and the SCA data are not actually required by the application, then setting NumSCAs to 1 will signficantly improve performance.
PollTime PollTime_RBV	bo ao	The EPICS driver rapidly polls the hardware when acquisition is active to detect when acquisition is complete. This record controls the poll time, which is typically .001 to .01 seconds. Decreasing the time decreases latency at the expense of more CPU time, and there is a minimum time required to poll the hardware. *Note: polling too fast can overload the system. I recommend 0.001 for the xMAP, 0.005 for the Mercury, and 0.010 for the Saturn.*
SaveSystemFile	waveform	The name of a file in which to save the system information. This file is created by the XIA Handel software, and is the ".ini" file format used in the call to xiaInit() in the startup script. This file can be used to transfer settings between XIA's programs (xManager, ProSpect) and EPICS. This is a waveform record with type DBF_UCHAR and length 256, rather than a stringout record, so that file paths/names longer than 40 characters can be used. Client applications must convert the file name to an unsigned char array when writing to this field.
SaveSystem SaveSystem_RBV	bo bi	Writing 1 to this record causes the system information to be written to the file specified by SaveSystemFile.
EnableClientWait	bo	This record enables waiting for a client when acquisition completes. It can be used to wait for a client application to save data to disk, etc.
SetClientWait	bo	This record sets the ClientWait record to Busy if EnableClientWait is set to Enable. This record is processed by EraseStart and StartAll in the dxpMED.template database.
ClientWait	busy	This record forces processing to wait until a client clears it after acquisition starts when EnableClientWait is set to Enable.

dxpSaturn.template

The following records are defined in the database dxpSaturn.template. One instance of this database is loaded for a Saturn system.

All of the record names in the template file are preceeded by the macro parameters (P)(R), where $(P) is the prefix for this detector system, and $(R) is the name of this specific channel.

- TraceMode. The choices for the TraceMode and TraceMode_RBV records are redefined from those in

dxpHighLevel.template to only include the first 2 choices, e.g. "ADC" and "Baseline history".

- PresetMode. The choices for the PresetMode and PresetMode_RBV records are defined from those in dxpHighLevel.template to only include "None", "Real time" and "Live time".
- TraceData. The NELM field is redefined from the 4096 value in dxpHighLevel.template to 4000, because that is the size of the trace array on the Saturn.
- TraceTime. The NELM field is redefined from the 4096 value in dxpHighLevel.template to 4000, because that is the size of the trace array on the Saturn.

Saturn medm screens

The following is the top-level medm screen for the DXP software. It loads the screens for each of the example IOCs.

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dxpTop.adl

Top-level DXP control screen.

The following are screen shots of the medm screens provided for the Saturn.

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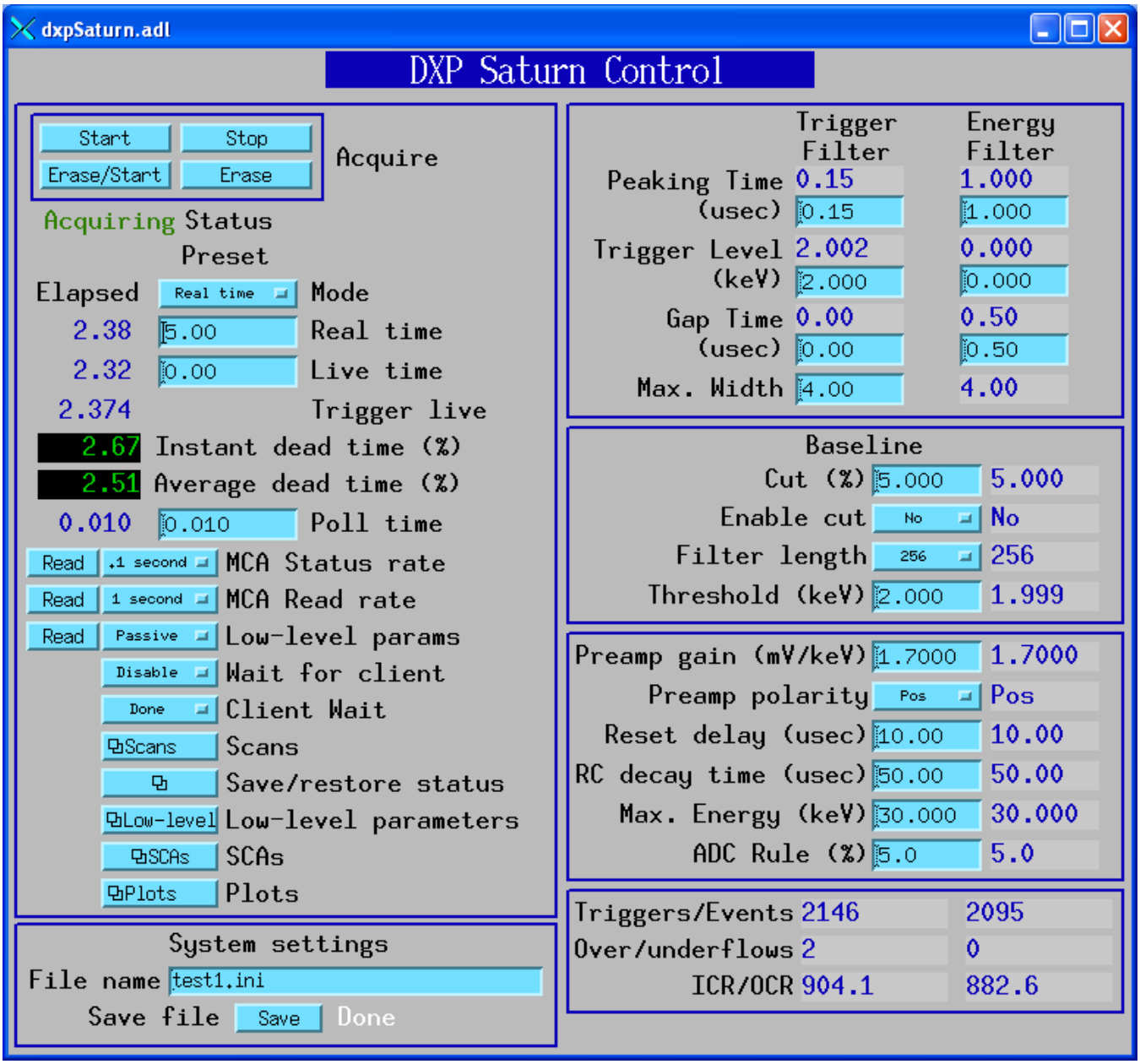
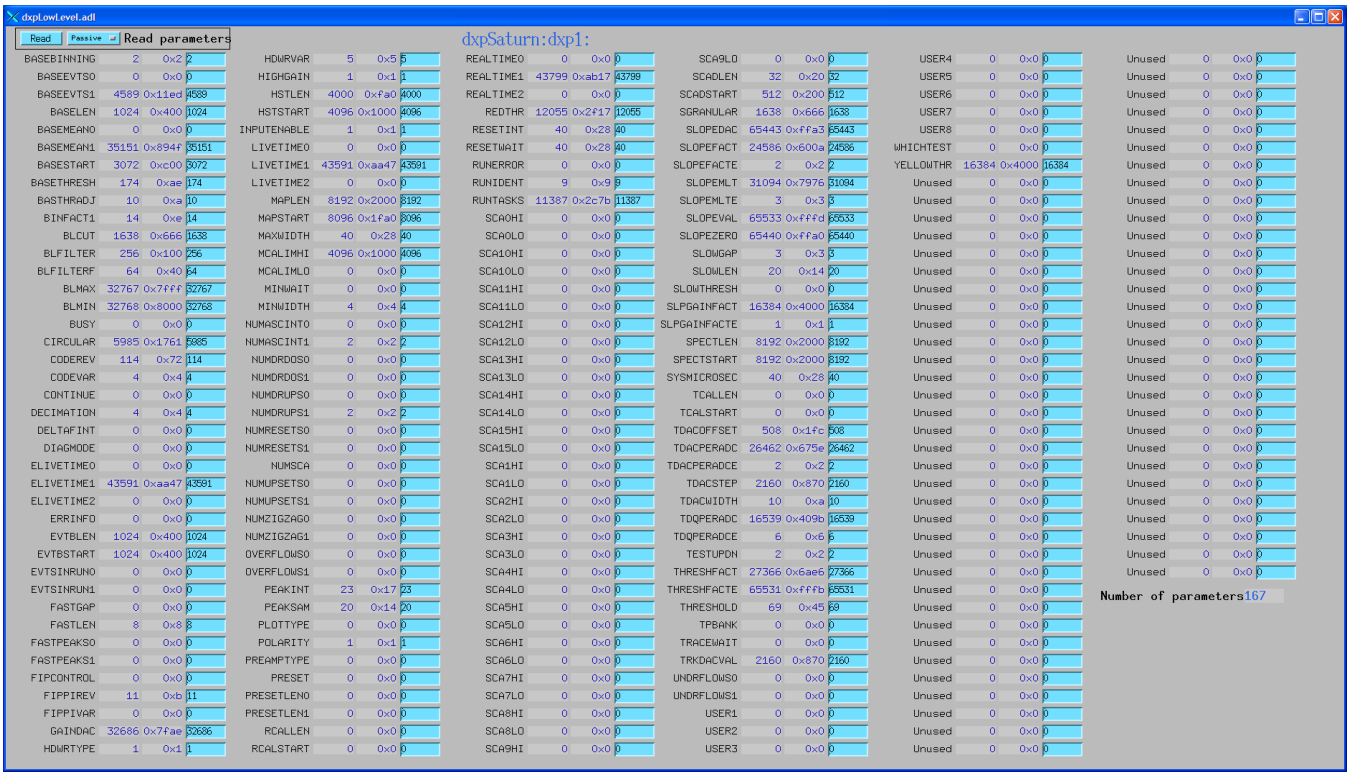
dxpSaturn.adl

Main control screen for Saturn.



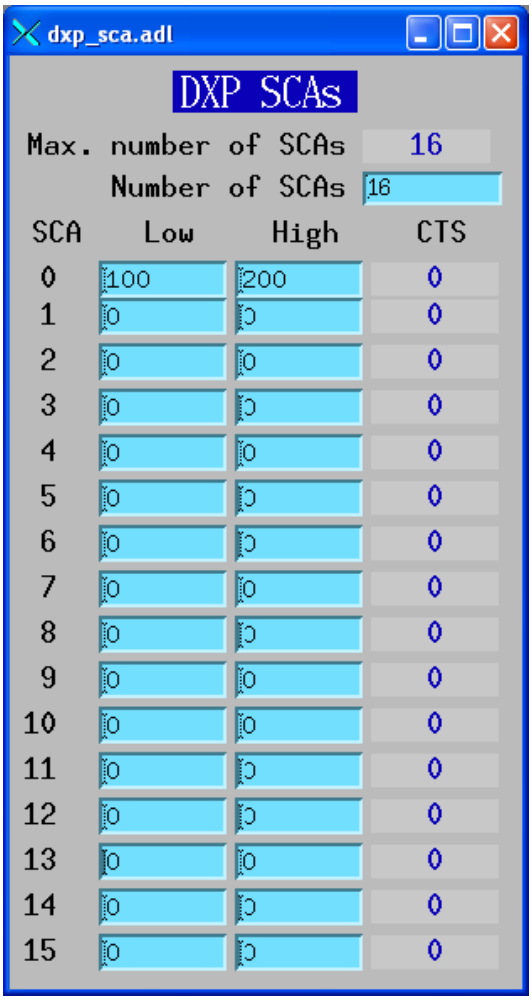
dxpLowLevel.adl

Complete screen for low-level DXP parameters and control.



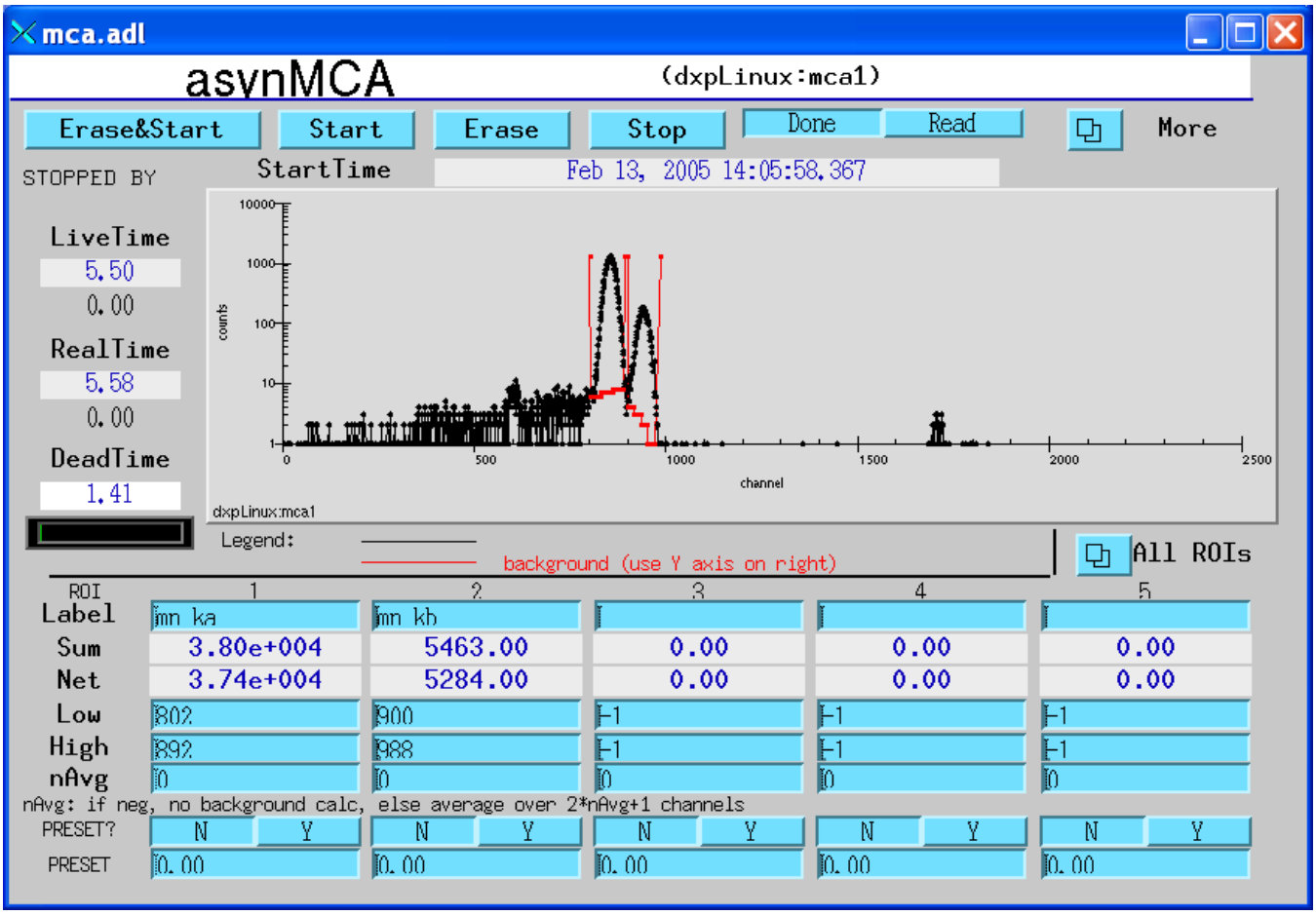
dxp_sca.adl

Screen for SCA display and control.



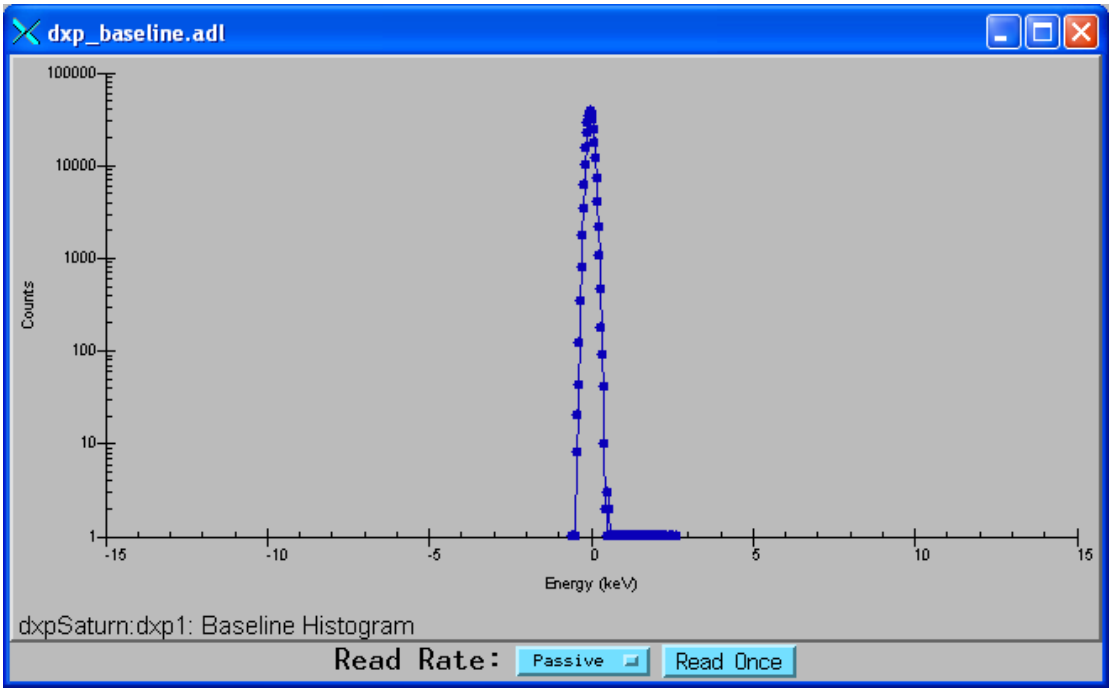
mca.adl

Screen to display the spectral data and control acquisition.



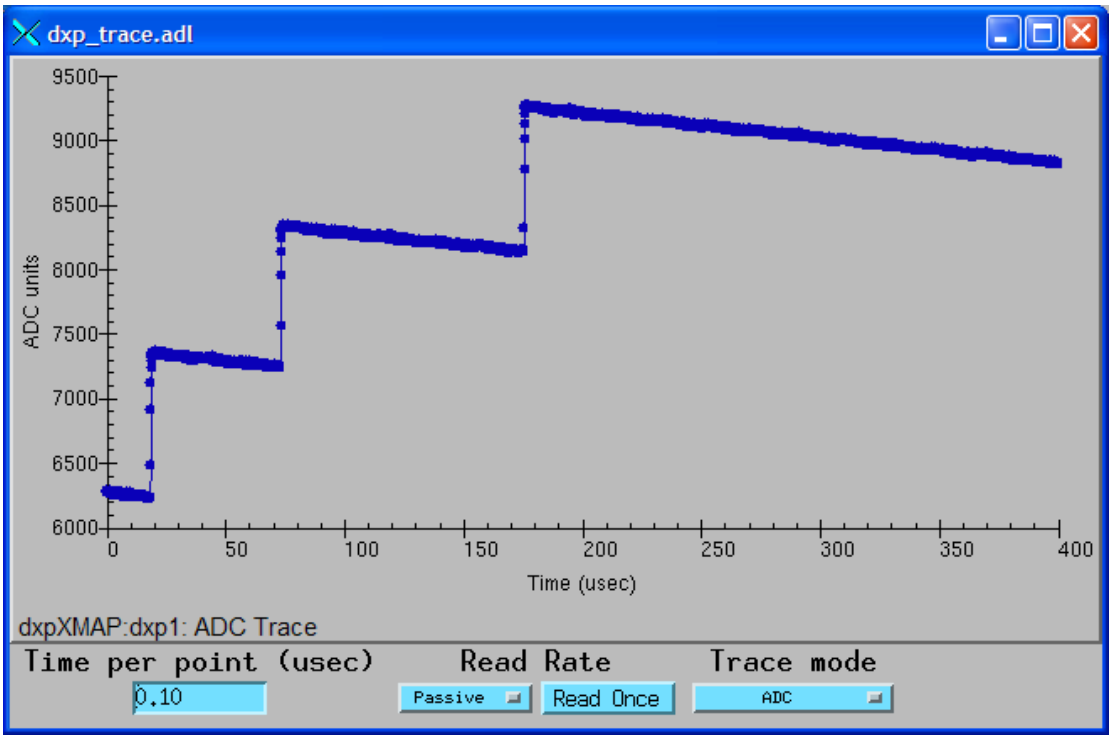
dxp_baseline.adl

Screen to display the baseline histogram and control its update rate.



dxp_trace.adl

Screen to display the ADC trace, and control the time per point and update rate.



dxpMED.template

The following records are defined in the database dxpMED.template (MED stands for Multi-Element Detector). One instance of this database is loaded for each multi-element (i.e. DXP2X, xMAP, and Mercury4) DXP system, since they control system-wide parameters. Only the records in this database that are intended for use by EPICS clients are documented here. Records that are not intended to be accessed from clients are not documented, since they may be changed in the future. Records in this database are implemented in several ways. Some are connected to an MCA record that is configured with a special address that signifies that it controls all detector channels. That record communicates directly with the driver. Other records are implemented in a State Notation Language program which monitors the system-wide records like PresetMode, and copies them to the individual detector records.

All of the record names in the template file are preceeded by the macro parameter $(P), the prefix for this detector system.

Records in dxpMED.template		
Record Name	**Record Type**	**Description**
SNL Status Records		
SNL_Connected	bi	This record will be 1 ("Connected") when the SNL program has connected to all of the PVs. If it is 0 ("Not connected") then there is a

		problem with the SNL program.
Acquisition Control Records		
EraseAll	bo	Writing 1 to this record erases all of the MCA records in this system.
EraseStart	bo	Writing 1 to this record erases and starts acquisition on all of the MCA records in this system. In the mapping modes it starts a new mapping run.
StartAll	bo	Writing 1 to this record starts acquisition on all of the MCA records in this system without first erasing any existing spectra. In the mapping modes it starts a new mapping run.
StopAll	bo	Writing 1 to this record stops acquisition in MCA and mapping modes.
Preset Control Records		
PresetMode	mbbo	The preset counting mode. On the xMAP and Mercury the choices are: • "No preset" Count until acquisition is stopped manually. • "Real time" Count for a preset real time. The real time is set by the PresetReal record. • "Live time" Count for a preset live time. The live time is set by the PresetLive record. • "Events" The output of the digital baseline filter. The preset number of events is set by the PresetEvents record. • "Triggers" The preset number of triggers is set by the PresetTriggers record. On the DXP2X only the first 3 choices are available, "Events" and "Triggers" are not supported. The preset counting modes only apply in normal MCA Spectra mode, they do not apply in any of the mapping modes.
PresetReal	ao	The preset real time.
PresetLive	ao	The preset live time. Note that since each channel on a module will typically have a different count rate (and hence different dead time), the channels will in general all stop counting at different times.
PresetEvents	longout	The number of events to count for. Note that counting on a module stops whenever any channel on that module reaches this value.
PresetTriggers	longout	The number of triggers to count for. Note that counting on a module stops whenever any channel on that module reaches this value.
Status/Statistics Records		
StatusAll	ai	Processing this record causes the status information (Acquiring, ElapsedReal, etc.) to be read. For maximum performance with short count times this record should have .SCAN=Passive. When this record is Passive the status information will still be read once when acquisition completes in normal MCA mode.
ReadAll	ai	

		Processing this record causes the MCA spectra to be read. For maximum performance with short count times this record should have .SCAN=Passive. When this record is Passive the MCA spectra will still be read once when acquisition completes in normal MCA mode. However, in order for the MCA spectra update in the MCA mapping mode this record must be set to periodically process (e.g. "2 second").
Acquiring	bi	Acquisition status, 0=Done, 1=Acquiring. Acquiring will be 1 if any channel is acquiring.
ElapsedReal	ai	The elapsed real time. This value is the maximum of the elapsed real time of all system channels.
ElapsedLive	ai	The elapsed live time. This value is the maximum of the elapsed live time of all system channels.
DeadTime	ai	The dead time. This value is the average of the dead time of all system channels. The dead time of each MCA is the cumulative dead time since the MCA was last erased.
IDeadTime	ai	The instantaneous dead time. This value is the average of the intantaneous dead time of all system channels. The instantaneous dead time of each MCA is the dead time in the interval since the MCA status was last read.
High-Level Parameter Records		
CopyTriggerPeakingTime	bo	Writing 1 to this record copies the TriggerPeakingTime from channel 1 to all channels.
CopyTriggerGapTime	bo	Writing 1 to this record copies the TriggerGapTime from channel 1 to all channels.
CopyTriggerThreshold	bo	Writing 1 to this record copies the TriggerThreshold from channel 1 to all channels.
CopyPeakingTime	bo	Writing 1 to this record copies the PeakingTime from channel 1 to all channels.
CopyGapTime	bo	Writing 1 to this record copies the GapTime from channel 1 to all channels.
CopyEnergyThreshold	bo	Writing 1 to this record copies the EnergyThreshold from channel 1 to all channels.
CopyMaxWidth	bo	Writing 1 to this record copies the MaxWidth from channel 1 to all channels.
CopyBaselineCutPercent	bo	Writing 1 to this record copies the BaselineCutPercent from channel 1 to all channels.
CopyBaselineCutEnable	bo	Writing 1 to this record copies the BaselineCutEnable from channel 1 to all channels.
CopyBaselineThreshold	bo	Writing 1 to this record copies the BaselineThreshold from channel 1 to all channels.

CopyBaselineFilterLength	bo	Writing 1 to this record copies the BaselineFilterLength from channel 1 to all channels.
CopyPreampGain	bo	Writing 1 to this record copies the PreampGain from channel 1 to all channels.
CopyDetectorPolarity	bo	Writing 1 to this record copies the DetectorPolarity from channel 1 to all channels.
CopyResetDelay	bo	Writing 1 to this record copies the ResetDelay from channel 1 to all channels.
CopyDecayTime	bo	Writing 1 to this record copies the DecayTime from channel 1 to all channels.
CopyMaxEnergy	bo	Writing 1 to this record copies the MaxEnergy from channel 1 to all channels.
CopyADCPercentRule	bo	Writing 1 to this record copies the ADCPercentRule from channel 1 to all channels.
Low-Level Parameter Records		
ReadLLParams	bo	Writing 1 to this record reads the low-level parameters for all channels. *Note: this record should be set to Passive during normal data acquisition, or it will slow things down.*
Trace and Diagnostic Records		
ReadBaselineHistograms	bo	Writing 1 to this record reads the BaselineHistogram for all channels. *Note: this record should be set to Passive during normal data acquisition, or it will slow things down.*
TraceModes	mbbo	This record sets the TraceMode for each channel. On the xMAP and Mercury the choices are: • "ADC" The equivalent of a digital scope trace of the pre-amp input to the module. • "Baseline history" A history of the baseline samples. • "Trigger filter" The output of the digital trigger filter. • "Baseline filter" The output of the digital baseline filter. • "Energy filter" The output of the digital energy filter. • "Baseline samples" The recent baseline samples. • "Energy samples" The recent energy samples. On the DXP2X only the first 2 choices are available, "ADC" and "Baseline history".
TraceTimes	ai	The time per sample in microseconds for the TraceData arrays.
ReadTraces	bo	Writing 1 to this record reads the TraceData for all channels. *Note: this record should be set to Passive during normal data acquisition, or it will slow things down.*
ROI and SCA Records		
CopyROIChannel	bo	

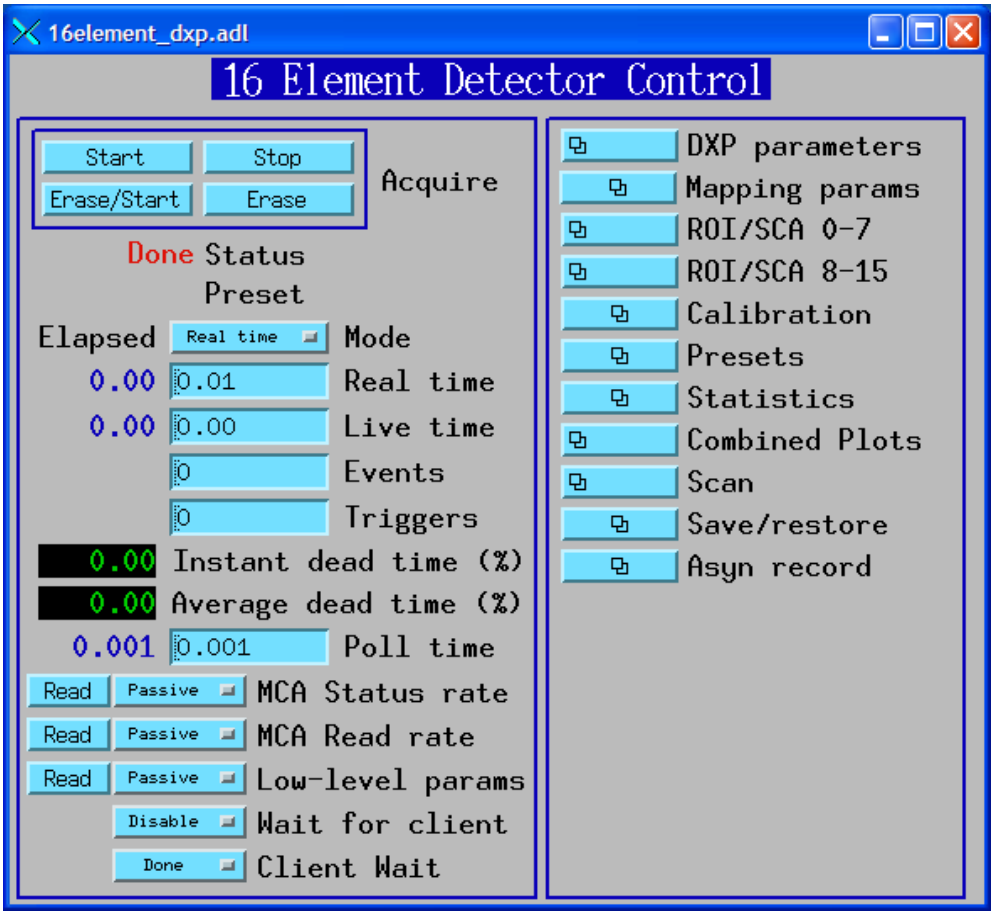
		Writing 1 to this record copies all ROIs from channel 1 to all channels on a channel-by-channel basis.
CopyROIEnergy	bo	Writing 1 to this record copies all ROIs from channel 1 to all channels on an energy-by-energy basis, i.e. using the energy calibration information for each MCA.
CopyROI_SCA	bo	Writing 1 to this record copies every ROI for every channel to the corresponding SCA.

Multi-element detector medm screens

The following are screen shots of the medm screens provided for multi-element detectors, e.g. xMAP, Mercury, and DXP4C2X.

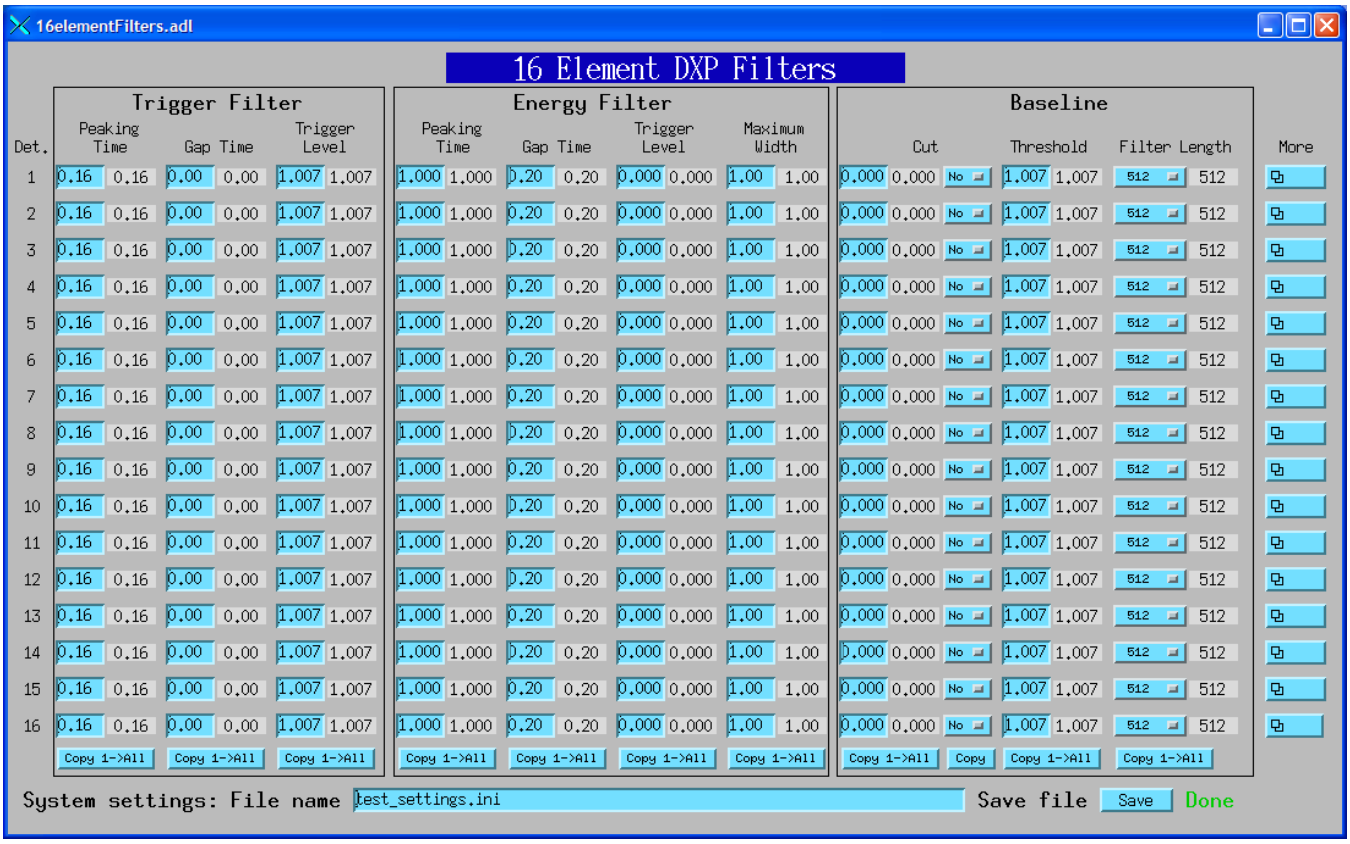
16element_dxp.adl

Main control screen for 16element system.

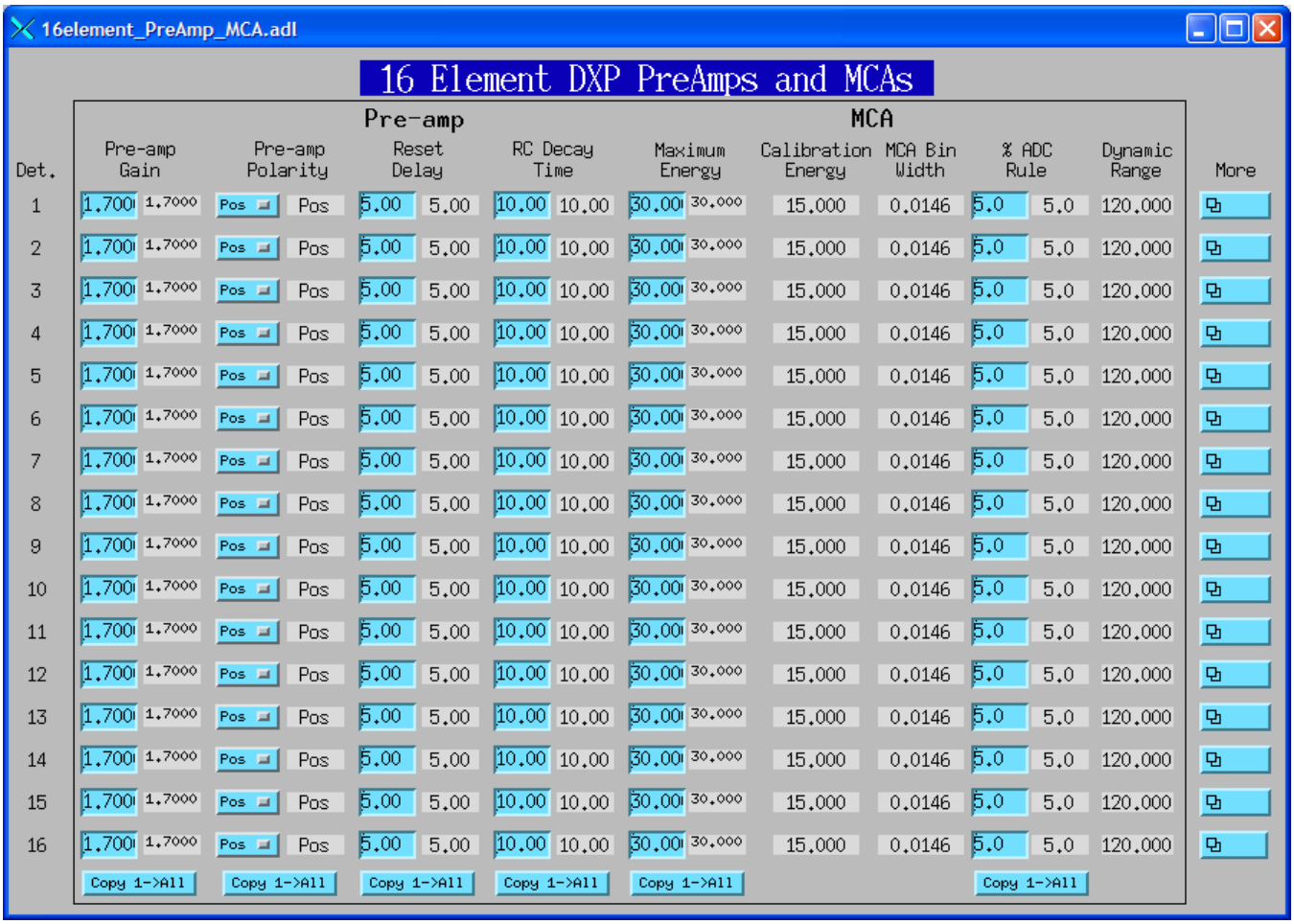


16elementFilters.adl

Screen to control DXP filter parameters.

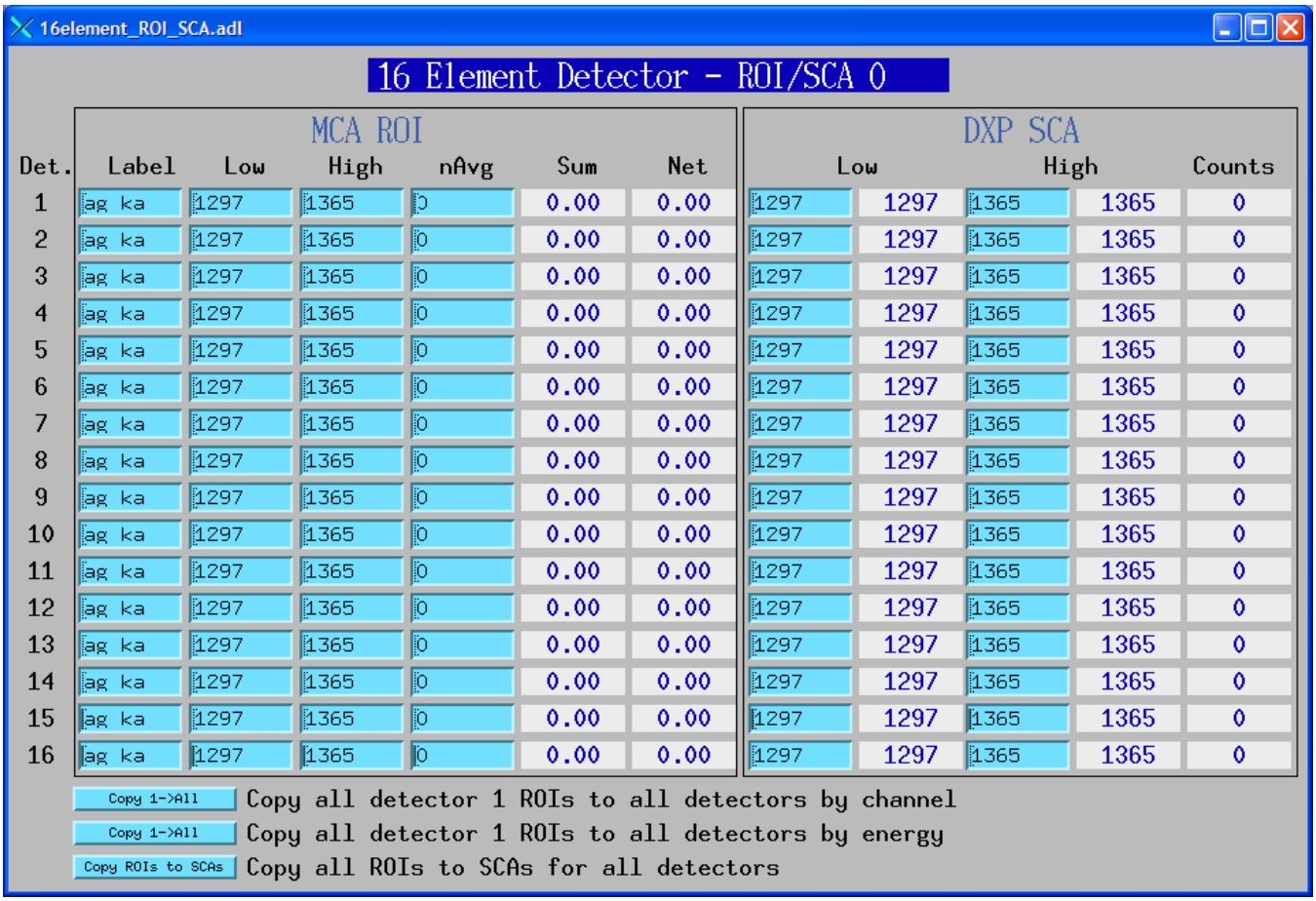


Screen to control DXP pre-amp and MCA parameters.



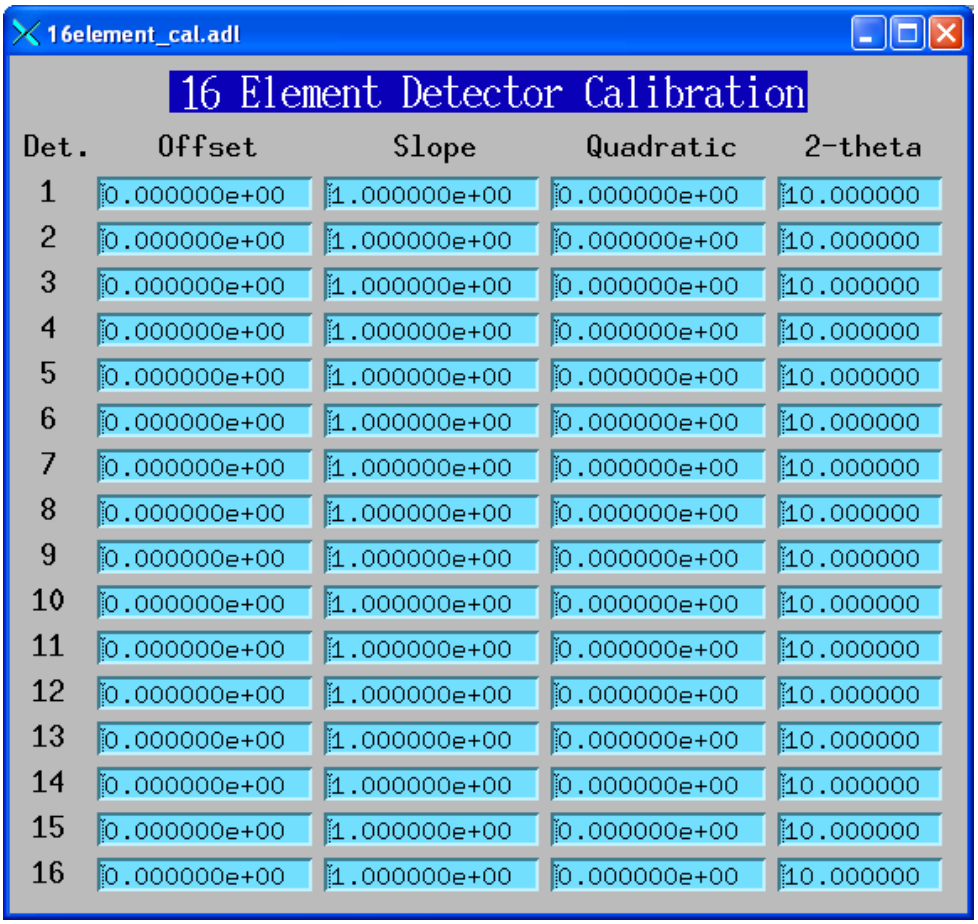
16element_ROI_SCA.adl

Screen to display ROI and SCA counts for a single ROI/SCA on each detector.



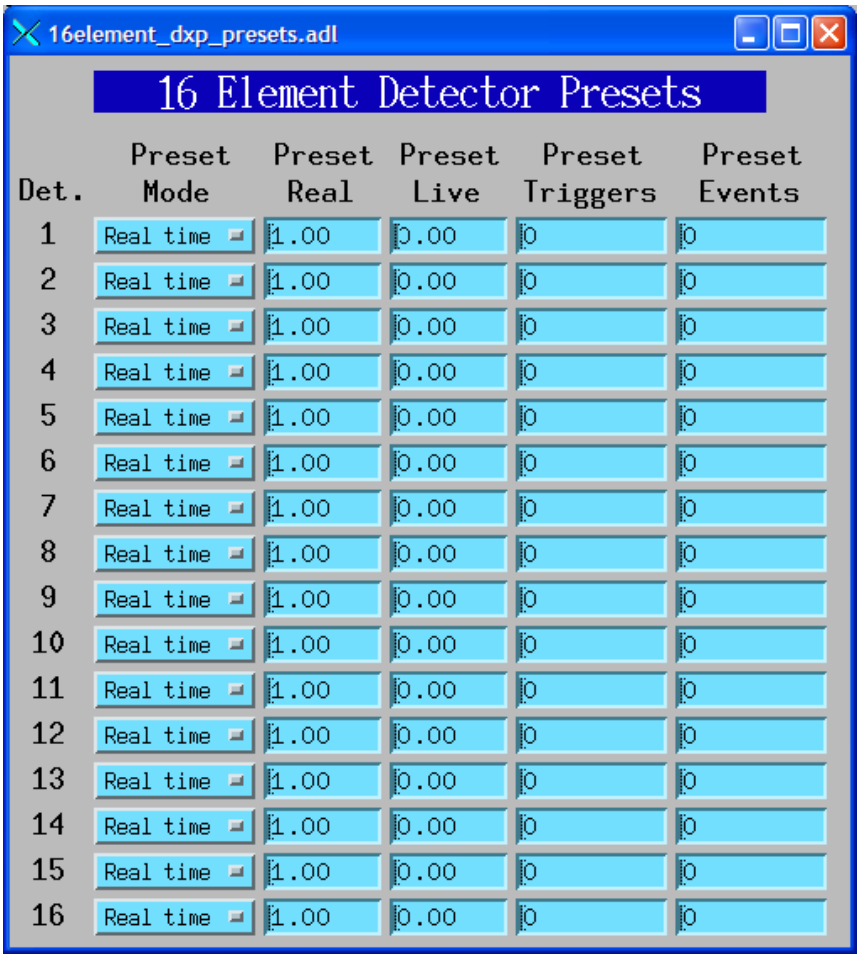
16element_cal.adl

Screen to display energy calibration parameters for each detector.



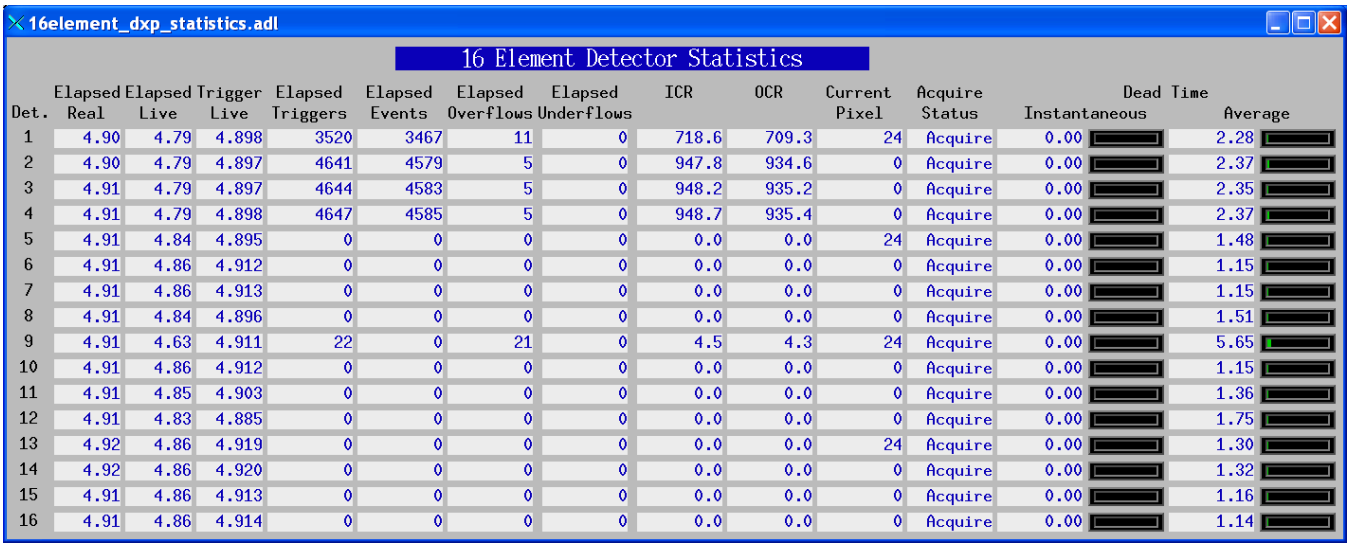
16element_dxp_presets.adl

Screen to display presets for each detector.



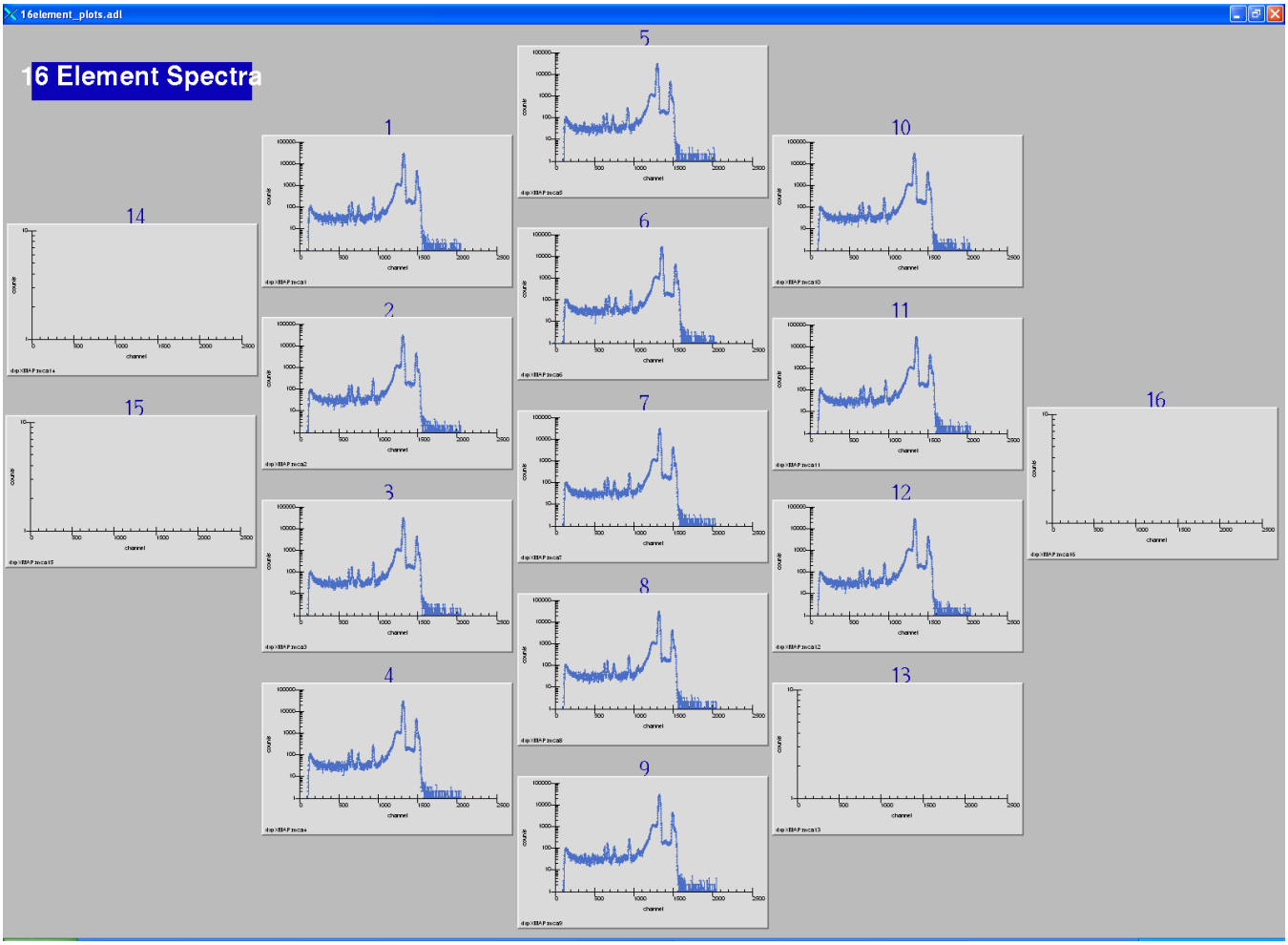
16element_dxp_statistics.adl

Screen to display the elapsed statistics for each detector.



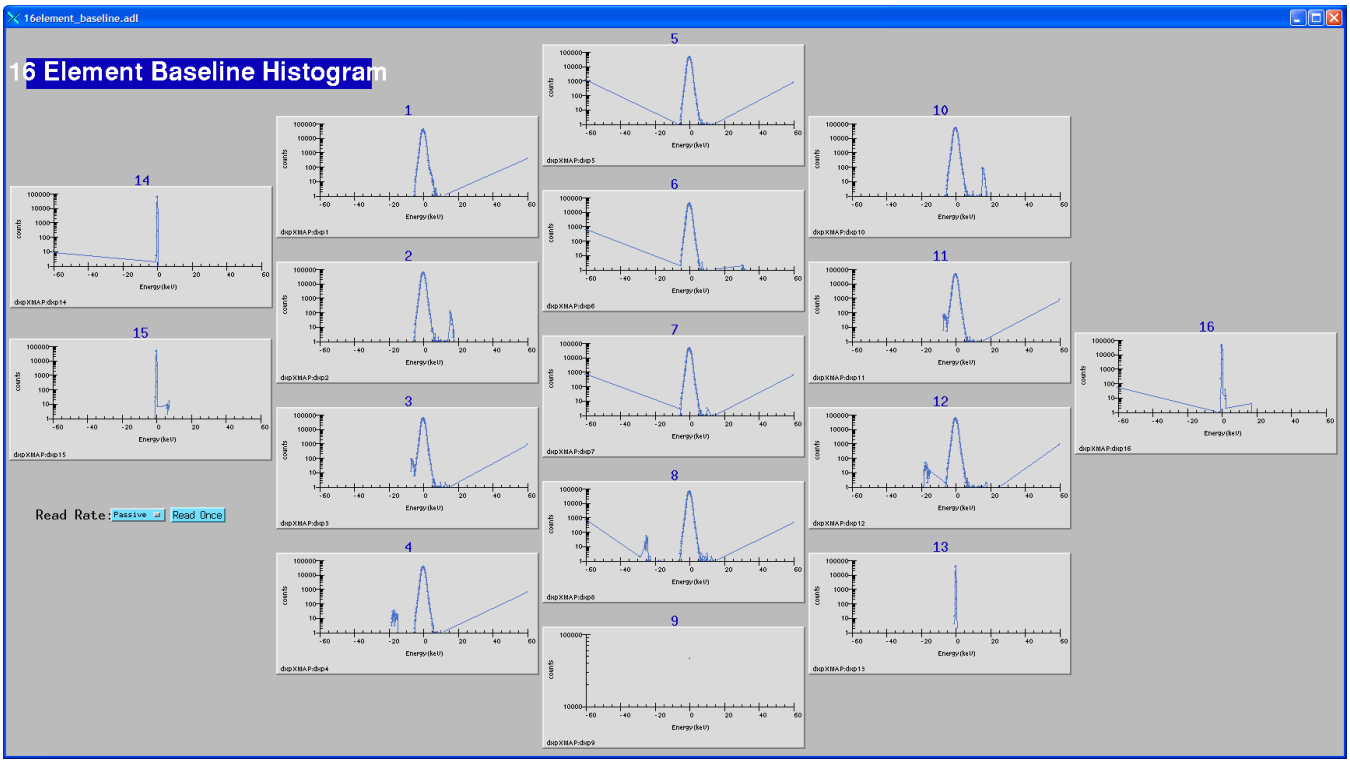
16element_plots.adl

Screen to display the spectral data for each detector.



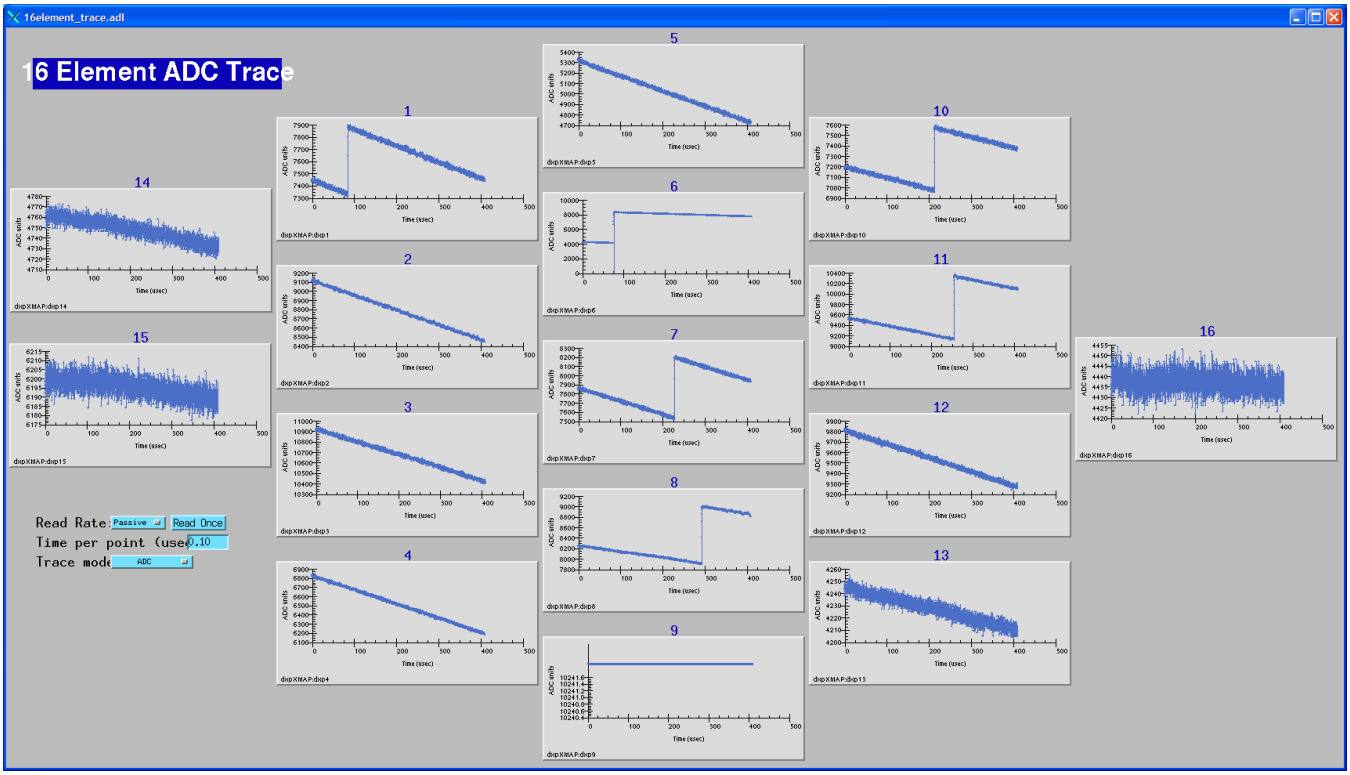
16element_baseline.adl

Screen to display the baseline histograms and control the update rate.



16element_trace.adl

Screen to display the ADC traces, and control the time per point and update rate.



dxpMapping.template

The following records are defined in the database dxpMapping.template. One instance of this database is loaded for an xMAP or Mercury system, since they control system-wide mapping parameters.

This document does not attempt to explain the mapping mode features of the xMAP or Mercury that these records control. The user should read the chapter on Mapping Mode in the xMAP User's Manual or Mercury User's Manual to understand the mapping features of these models. The short document on using the Handel library for mapping mode on the xMAP Handel Quick Start Manual for the xMAP can also be useful. Though the material discussed there was mostly useful for writing the EPICS driver, it can also help to understand how the system works.

All of the record names in the template file are preceeded by the macro parameter $(P), the prefix for this detector system.

Records in dxpMapping.template		
Record Name	**Record Type**	**Description**
Mapping Mode Control Records		
CollectMode CollectMode_RBV	mbbo mbbi	Selects the collection mode for the system. The choices are: • "MCA spectra" Normal MCA spectra mode where individual spectra are collected with the MCA record. • "MCA mapping" MCA mapping mode where MCA spectra are collected into the double-buffered memory. • "SCA mapping" SCA mapping mode where the total counts in up to 32 SCAs are collected into the double-buffered memory. • "List mapping" List-mode mapping mode where the energy of each x-ray event is collected into the double-buffered memory. Depending on the value of the ListMode record the time of each event (20 ns resolution) or the pixel number of each event is also collected. Note: the Mercury firmware currently only supports "MCA spectra" and "MCA mapping" modes.
ListMode ListMode_RBV	mbbo mbbi	Selects the list mode variant when CollectMode="List mapping". The choices are: • "E & Gate" The Gate input signal is used to advance the pixel number. The energy and pixel number of each event are collected into the double-buffered memory. • "E & Sync" The Sync input signal is used to advance the pixel number. The energy and pixel number of each event are collected into the double-buffered memory. • "E & Clock" The energy and clock time since acquisition was started (20 ns resolution) are collected into the double-buffered memory.

PixelAdvanceMode PixelAdvanceMode_RBV	mbbo mbbi	Selects the pixel advance mode for system. The choices are: • "Gate" Transitions on the Gate hardware input signal are used to drive the pixel advance. On xMAP systems one (and only one) xMAP module on each PCI bus segment in the system must be a "gate_master" to use this mode. • "Sync" Transitions on the Sync hardware input signal are used to drive the pixel advance. on xMAP systems one (and only one) xMAP module on each PCI bus segment in the system must be a "sync_master" to use this mode. For systems with more than one xMAP module, one module on each PCI bus segment can be gate_master, another module can be sync_master, and PixelAdvanceMode can be changed between Gate and Sync. *Note: there is a bug in the current xMAP firmware, so that a module defined to be a sync_master will always use its pulse input for pixel_advance, even if another module is defined to be gate_master, and PixelAdvanceMode is defined to be Gate. This should be fixed in a future firmware release, but for now if a sync_master is defined in the system then only use Sync for PixelAdvanceMode.*
NextPixel	bo	Writing 1 to this record causes the system to advance to the next pixel in MCA mapping or SCA mapping modes. This is a "software" pixel advance, and can be issued any time mapping mode acquisition is in progress, regardless of the setting of PixelAdvanceMode.
PixelsPerRun PixelsPerRun_RBV	longout longin	The total number of pixels to acquire in one "run" when acquisition starts. If this value is -1 then there is no preset number of pixels, and acquisition will continue forever until it is stopped manually with StopAll. This value only applies in MCA mapping and SCA mapping modes, not in List mapping mode.
PixelsPerBuffer PixelsPerBuffer_RBV	longout longin	The number of pixels per buffer. If AutoPixelsPerBuffer=Manual, then this value is used, rather than using the maximum possible value computed when AutoPixelsPerBuffer=Auto. The main reason to set this value manually is that the updates to statistics and MCA displays in mapping mode happen only when a buffer is read out. If the time per pixel is relatively long then decreasing PixelsPerBuffer will result in more frequent updates of the MCA and statistics displays. Setting this value too low when doing rapid mapping can result in buffer overflow. PixelsPerBuffer_RBV always contains the actual number of pixels per buffer.
AutoPixelsPerBuffer AutoPixelsPerBuffer_RBV	mbbo mbbi	Flag controlling how the number of pixels per buffer is determined. Choices are 0=Manual and 1=Auto. If Manual is selected then the number of pixels per buffer is controlled by the PixelsPerBuffer record. If Auto is selected then the maximum number of pixels that the 2MB mapping buffer can hold is automatically computed.
BufferSize_RBV	longin	The size of the buffer being used in units of 16-bit words. This will be the first dimension of the array passed to the plugins when a buffer is read out. The maximum value is 1M=1048576, but it can be less than

		this depending on the value of PixelsPerBuffer_RBV.
IgnoreGate IgnoreGate_RBV	mbbo mbbi	Flag controlling whether the Gate input signal is used to inhibit counting. Choices are 0=No and 1=Yes. If IgnoreGate=Yes then the Gate input can be used as a pixel advance signal, but its high or low state will not influence whether counting is enabled, i.e. only the transitions are significant. If IgnoreGate=No then counting will be inhibited when the Gate input is low (if InputLogicPolarity=Normal) or high (if InputLogicPolarity=Inverted).
InputLogicPolarity InputLogicPolarity_RBV	mbbo mbbi	Flag controlling the polarity of the Gate input signal. Choices are 0=Normal, 1=Inverted. In Normal mode a low level on the Gate input inhibits counting (if IgnoreGate=No) and a high-to-low transition performs a pixel advance (if PixelAdvanceMode=Gate). In Inverted mode these levels are the opposite, i.e. a high level inhibits counting and a low-to-high transition performs a pixel advance.
SyncCount SyncCount_RBV	longout longin	The divisor used on the Sync input for pixel advance if PixelAdvanceMode=Sync. Allowed values are 1 to 65,535. This value can be used to divide the Sync clock. For example, if the Sync input were connected to the pulse output of a stepper motor controller, then setting SyncCount=10 would perform a pixel advance on every 10'th stepper motor pulse. SyncCount=1 results in no clock division, i.e. every Sync input pulse results in a pixel advance.
ReadRate_RBV	ai	The burst read rate in MBytes/s measured when reading the mapping data from each module.
MBytesRead_RBV	ai	The total number of MBytes of mapping data read from all modules since the IOC started.
Parameter Download Control Records		
AutoApply AutoApply_RBV	mbbo mbbi	Flag controlling whether parameters are automatically downloaded to the hardware ("apply" operation) each time a parameter is changed, or whether they are only downloaded when the Apply record is set to 1. Choices are 0=No, 1=Yes. This flag can dramatically affect performance, because the process of downloading parameters to the xMAP or Mercury is very slow, requiring about 0.3 seconds. If many parameters need to be changed it is much faster to do the following: 1. Set AutoApply=No 2. Change a number of parameters 3. Write 1 to the Apply record 4. Set AutoApply back to Yes The EPICS driver sets AutoApply=No when the driver is initialized. This means that all of the parameter setting that occurs during driver initialization and during iocInit when the records are initialized by EPICS is very fast because the values are not actually downloaded to the hardware. At the end of the EPICS startup script there are "dbpf" commands to write 1 to the Apply record (forcing a download), and to set AutoApply=Yes. Most operations that the users will do involve

		setting a only a few parameters, such as PeakingTime, etc. These are fast even with AutoApply=Yes, so it is normally left in this state. That way the user does not have to worry about performing a manual apply operation with the Apply record. The one operation that does involve setting a very large number of parameters is processing the CopyROI_SCA record, which redefines all of the SCAs for each detector. This is handled by the SNL program, which does the following: 1. Saves the current state of AutoApply 2. Sets AutoApply=No 3. Copies all of the new SCA parameters for each detector from the MCA records 4. Writes 1 to the Apply record 5. Sets AutoApply back to previous value This performance optimization was added in R3-0, and reduces the time to copy ROIs from several minutes in previous releases to less than 2 seconds in R3-0 for a 16-channel xMAP system.
Apply	longout	Writing 1 to this record forces an "apply" operation, downloading the parameters for all channels to the hardware. This is not needed if AutoApply=Yes, but it can greatly improve performance to set AutoApply=No and write to this record after modifying a large number of parameters.

Using mapping modes with the xMAP and Mercury

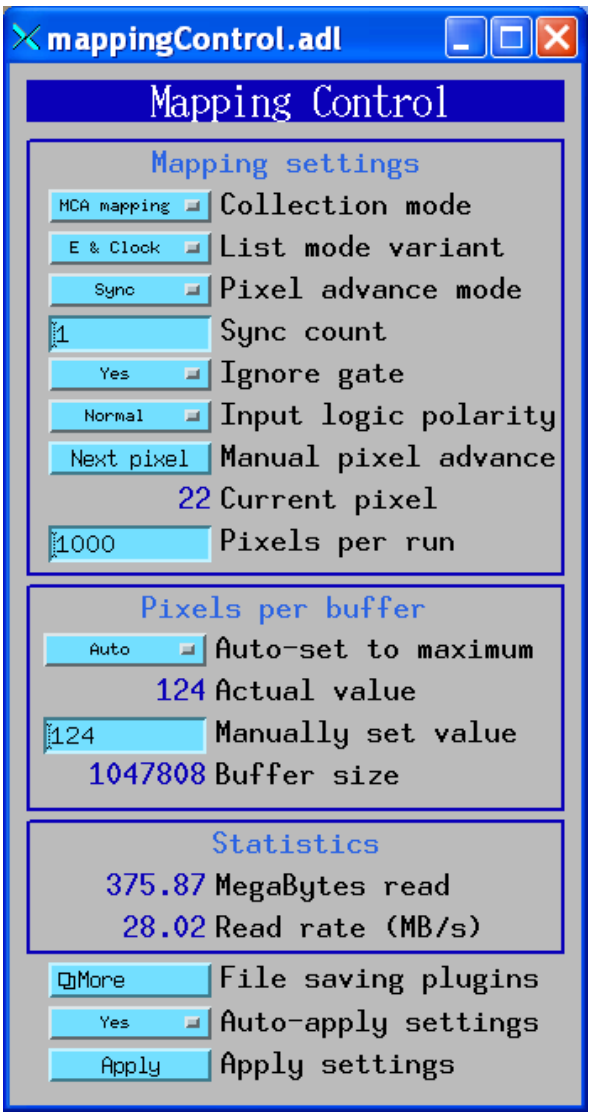
In the mapping modes on the xMAP and Mercury data are collected into a double-buffered memory on the module. When one half of the buffer memory is full the EPICS driver reads the data from that buffer into an NDArray object. It then calls any registered plugins with that NDArray. The plugins will typically be one of the NDPluginFile plugins which will write the data to disk. The useful file plugins can write the data in netCDF, NeXus/HDF5, and TIFF formats. The JPEG plugin will not be useful, because the data are not images. The data can also be passed to the NDPluginStdArrays plugin which can make the data available to EPICS channel access clients as waveform records.

The data in each NDArray object is a 16-bit unsigned integer array with dimensions [BufferSize, ModulesPerSystem]. BufferSize is the size of the double-buffered memory in use, which is controlled by the AutoPixelsPerBuffer and PixelsPerBuffer records. It has a maximum value of 2^20 (1048576) but can be smaller than this. ModulesPerSystem is the total number of xMAP modules in the system, and is always 1 for the Mercury. In MCA mapping and SCA mapping modes the buffer for each module in this array contains the data for each pixel, including the elapsed live and real time, triggers and events, and the MCA or SCA data. In List mapping mode the buffer contains the event data for each x-ray event. The details of the buffer structure are beyond the scope of this document, but the buffer structure is thoroughly described in the section entitled "Mapping Mode Data" in the xMAP User's Manual and Mercury User's Manual.

The EPICS software does not provide records to configure the Gate, Sync, or LBUS masters in the system. This is because there can be a variable number of these depending on how many PCI bus segments the xMAPs use. The Gate, Sync, and LBUS masters should be configured with the xManager configuration wizard, or by directly editing the .ini file. The values for the masters in the .ini file will be used, EPICS does not modify them.

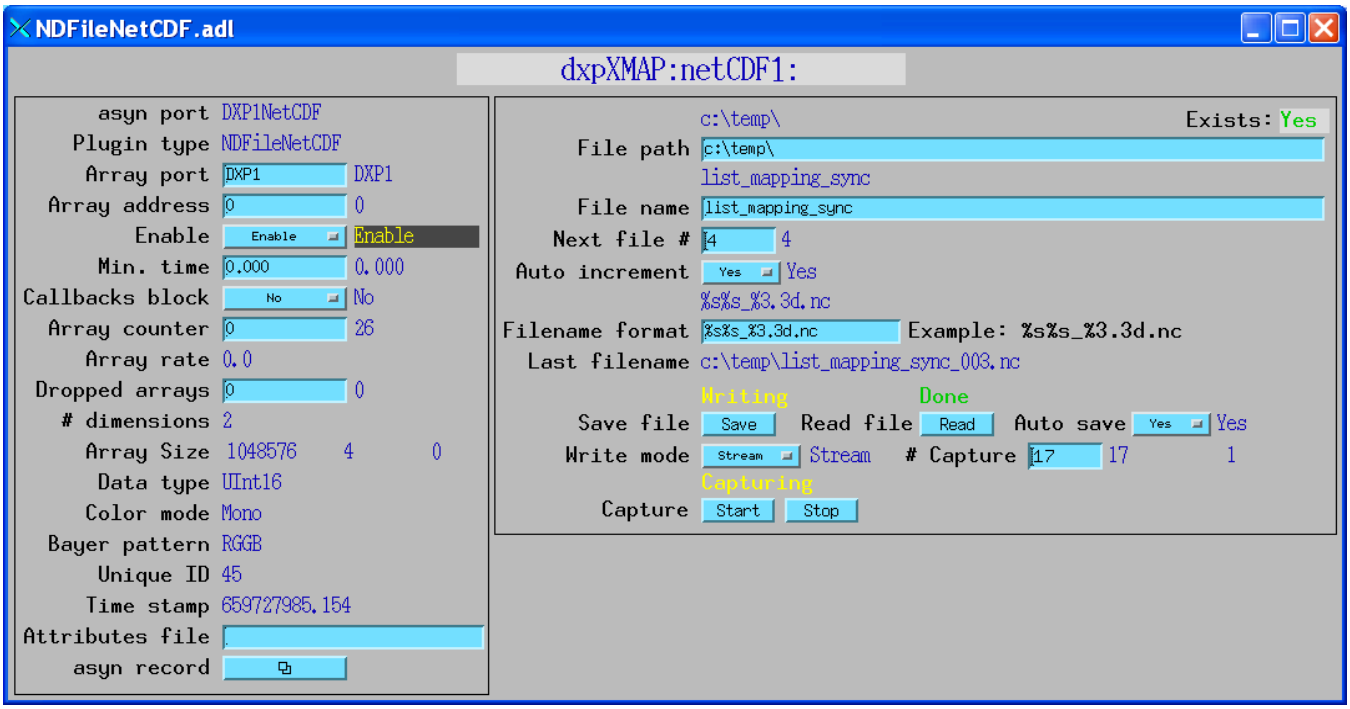
The following medm screen is used to configure the mapping modes on the xMAP and the Mercury.

mappingControl.adl



The following medm screen is used to configure the netCDF file plugin to save mapping mode data on the xMAP and the Mercury.

NDFileNetCDF.adl



To collect mapping mode data one would typically execute the following steps:

1. Select the mapping mode (CollectMode record)
2. In MCA mapping and SCA mapping modes:
    - ♦ Select the pixel advance mode (PixelAdvanceMode record)
    - ♦ Select the number of pixels per run (PixelsPerRun record)
3. In List Mapping mode:
    - ♦ Select the list mode variant (ListMode record)
4. In the netCDF plugin
    - ♦ Set the Enable record to Enable.
    - ♦ Set the FilePath, FileName, FileNumber, FileTemplate, AutoIncrement, FileWriteMode, NumCapture, and Autosave records to the desired values. Typically AutoIncrement=Yes, FileWriteMode=Stream, NumCapture= number of buffers to be captured = PixelsPerRun/PixelsPerBuffer.
    - ♦ If FileWriteMode is Stream or Capture then start capture/streaming with the Capture record. *NOTE: Before stream or capture can be started there must have been at least 1 callback to the plugin in the current mapping mode with the same CollectMode and PixelsPerBuffer currently in use. This is because stream and capture modes need to know the buffer size that will be received at the time that capture/streaming is started. This can be done by simply enabling the file plugin and doing a quick run. Just start a run, advance a few pixels with the NextPixel record, and stop the run. Even though only a few pixels have been collected the entire buffer is read out, so the size is correct.*
5. Start acquisition with the EraseStart record.
6. In MCA mapping or SCA mapping modes do something that causes the pixels to advance. This could be using the NextPixel record, or an external advance source such as a pulse generator, motor pulse train, etc. In List mapping modes the buffer fills up with event data even if the Sync or Gate pixel clock is not advancing.
7. Each time a buffer fills up the netCDF plugin will be called, writing data to disk.
8. In MCA mapping mode each time the buffer fills up the MCA spectra for the first pixel in that buffer will be sent to the MCA records, so they can be displayed. This provides a periodic visual feedback on the

MCA data.

9. In MCA and SCA mapping modes once the requested number of pixels per run has occured acquisition will automatically stop. In List mapping mode acquisition must be manually stopped with the StopAll record.
10. If the netCDF plugin is in stream or capture mode and NumCapture was specified correctly, then it will also automatically stop capturing when the last buffer is received. If NumCapture was 0 or was too large, then stream/capture should be manually stopped by writing 0 to the Capture record.

Data acquisition in mapping mode is very flexible. When doing a 2-D map, for example, one could stream the data for the entire map into a single large netCDF file. Alternatively, one could save just a single scan row into each file, and restart the file plugin for each row, using a new file name, or auto-increment on the file number. Data can also be saved into NeXus or TIFF files, rather than netCDF files.

Which mapping mode to use depends on the needs of the experiment. If only the counts in ROIs are needed then it is most efficient to collect data in SCA mapping mode. The counts in the SCAs are the total counts, with no background subtraction. However, it is possible to define additional SCAs in regions of no peaks, and correct for background during post-processing by using these "background" SCAs to estimate the background counts per channel. List mapping mode can be used to collect data with very high time resolution (20 ns). It is also often more faster and more efficient in disk space than MCA mapping mode, with essentially the same information. The speed and file size in List mapping mode depends of course on the number of x-rays per second. Each x-ray event requires 6 bytes (2 for the x-ray energy, and 4 for the clock time or pixel number). Consider a 4-detector xMAP system with a count rate of 100,000 cps per detector. The total data rate in List mapping mode will be 4 detectors * 100,000 events/s * 6 bytes/event = 2.4 MB/sec. That can be compared to running the same system in MCA mapping mode with 2048 channel spectra at the fastest possible pixel rate, 1000 pixels/s. In that case the data rate is 4 detectors * 2048 channels * 2 bytes/channel * 1000 pixels/s = 16MB/s. In this case List mapping results in almost 7 times less data than MCA mapping, because most of the spectral channels are 0 in MCA spectra mode. The only significant difference is that in list mode there is no measure of live time at each "pixel", and it will require more post-processing to arrange the data into spectra, if that is what is desired.

This is a Python program called fast_mapping.py that implements such a 2-D scan. This is a simple program that was written by Yan Fen and me at the SSRF (Shanghai Synchrotron). It works as follows:

- The system contains an SIS3820 multi-channel scaler. This has its external channel advance connected to the stepper motor pulses driving the X sample stage. The External Prescale is set to divide these pulses by the number of motor pulses per pixel. Each time the X stage motor moves by this amount the SIS3820 collects the data from the ion chamber (I0) and other counter inputs into its MCA records. It also outputs a trigger pulse on its CIP output, which is input into the xMAP Sync input to do a pixel advance on the xMAP.
- There are 2 EPICS sscan records.
    - X15U1:test:scan1 is the fast inner scan. It drives the X stage motor. It is configured to collect 1-D arrays, which are the SIS3820 MCA records. These are saved into MDA files by the saveData utility in EPICS. It has detector triggers for the SIS3820 EraseStart PV. However, this is just to forces the sscan record wait until the SIS3820 is done at the end of the row. It is actually necessary to start the SIS3820 and xMAPs *before* the scan starts. This is because the sscan record begins moving the motor before it fires its detector triggers, and that will not work here, they need to start counting *before* the motor starts moving. When each row is collected this scan is started by the Python script. It will save the SIS3820 counters into a separate MDA file for each row, because it does not think a 2-D EPICS scan is in progress.
    - X15U1:test:scan2 is the slow outer scan. Its positioner is the Z stage motor. However, we are only using this scan as a convenient place for the user to enter the start, end, step size and number of points of the Z scan. This scan record is not actually executed. Rather the Python program

reads the PVs for this scan and moves the motor itself. The reason for this is that there are things that need to be done at the start of each row that are much more easily done in the Python program than in the sscan record. This includes setting up the netCDF file plugin, starting the SIS3820 and xMAP, etc.

- At the very beginning of the 2-D scan the Python code does the following:
  - Reads the size of the scan in the X and Z directions (nFast, nSlow) from the sscan records.
  - Writes nFast into the NuseAll PV of the SIS3820 so that it stops after this many channel advances. It also writes nFast into the xMAP PixelsPerRun PV to set the number of pixels per run.
  - Computes the number of xMAP buffers that each scan row will require. This is ((nFast+1)/124 + 1), because each buffer can hold 124 pixels when collecting 2048 channel spectra. (To be more general it should read the value of PixelsPerBuffer from the xMAP rather than hardcoding 124). Writes this value into the NumCapture PV of the netCDF plugin.
  - Writes the desired base file name into the FileName PV of the netCDF plugin.
  - Writes 1 into the FileNumber PV of the netCDF plugin. The netCDF file plugin was also previously configured to have a valid FilePath, AutoIncrement=Yes, and FileTemplate="%s%s_%d.nc". It was thus saving files with names like MyScan_1.nc, MyScan_2.nc, ... for rows 1, 2, ... of the scan.
  - Sets the netCDF file plugin FileWriteMode PV to Stream (choice 2). This means that all of the pixels for one scan row will be streamed into a single netCDF file.
- The Python program then executes a 1-D loop over the number of rows (Z stage pixels) in the scan. For each row of the scan it does the following:
  - Starts the netCDF plugin streaming by writing 1 to the Capture PV.
  - Sets the speed of the X stage motor to its fast flyback speed.
  - Starts the X stage moving to the start position.
  - Starts the Z stage moving to the position for this row.
  - Waits for the X and Z stages to arrive at their target positions.
  - Sets the speed of the X stage motor to the desired scan speed (i.e. pixel size / time per pixel).
  - Erases and starts the SIS3820.
  - Erases and starts the xMAP. Waits 0.5 seconds after this to allow the xMAP to be ready.
  - Starts the fast scan (scan 1). That will start the X stage moving, and will wait for the SIS3820 to complete. saveData will write the SIS3820 MCA data to the MDA file at the end of the scan row.
  - Waits for the xMAP to be done.

There are IDL functions available in the CARS IDL detector package to conveniently extract the MCA, SCA, or List mode data from netCDF files produced with the netCDF plugin. read_xmap_netcdf.pro reads mapping data from a single netCDF file. It calls read_nd_netcdf.pro and decode_xmap_buffers.pro. read_xmap_2d.pro is an IDL procedure that calls read_xmap_netcdf.pro to read all of the netCDF files for an entire 2-D scan collected by programs such as the Python program described above.

The following is an IDL program that calls read_xmap_2d for a 501x500 scan of a Ni mesh. It extracts the Ni Ka peak (channels 716 to 776) from the data. It sums over all the channels in this region, normalizes by live time, sums over all 7 detectors, and finally displays the image with the IDL iTools iimage procedure.

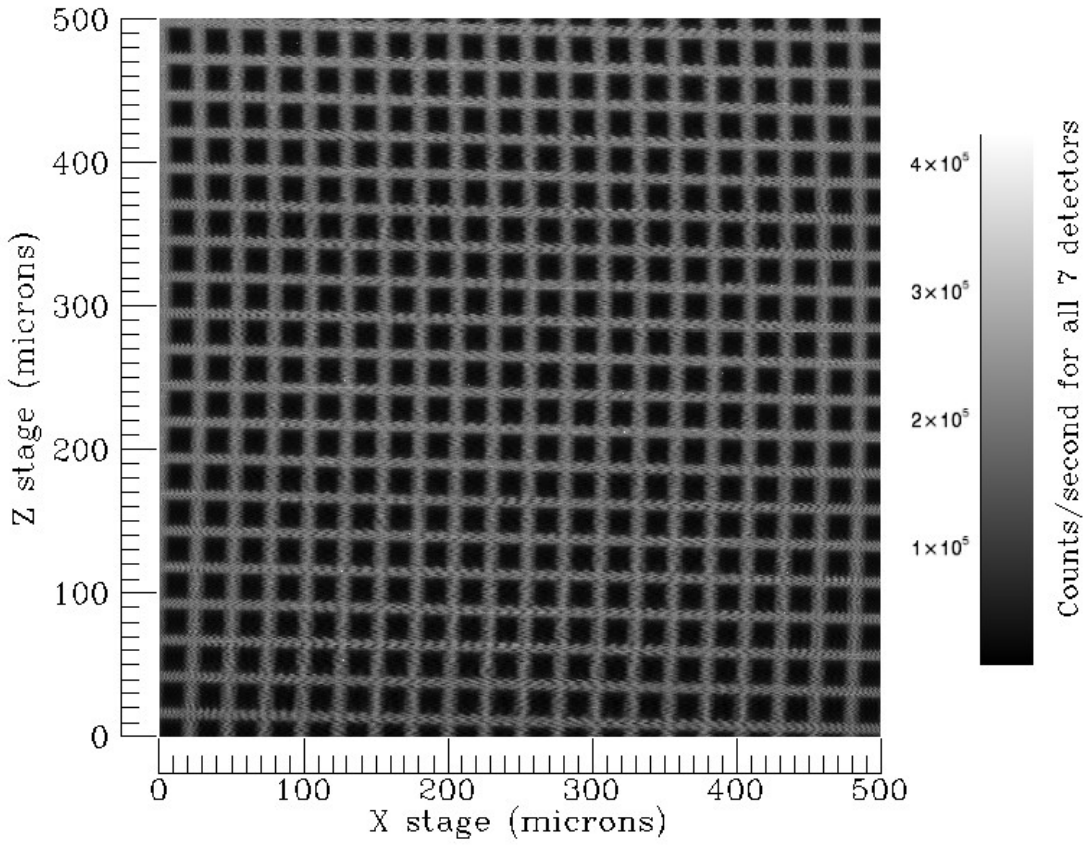
```
; Read data, only channels 716 to 776
d = read_xmap_2d('Scan4_', 501, live_time=live_time, real_time=real_time, $
                 events=events, triggers=triggers, channel=[716,776])
; Sum over channels 716 to 776 (first dimension)
tot = total(d, 1)
; Divide by live time for each detector for each pixel, but live=0 increase to .001
tot1 = tot/(live_time>.001)
; Sum over the detectors
```

```
    tot2 = total(tot1, 1)
    ; Display
    iimage, tot2
end
```

This scan was done at SSRF with the following parameters:

- 1x1 micron pixels.
- 500x501 pixel scan.
- 2.5 ms per pixel
- 7-element Si(Li) detector with 2 xMAP modules.
- Total scan time was 38 minutes

This is the image produced from the "iimage" command in the above program after interactively adding some annotation.

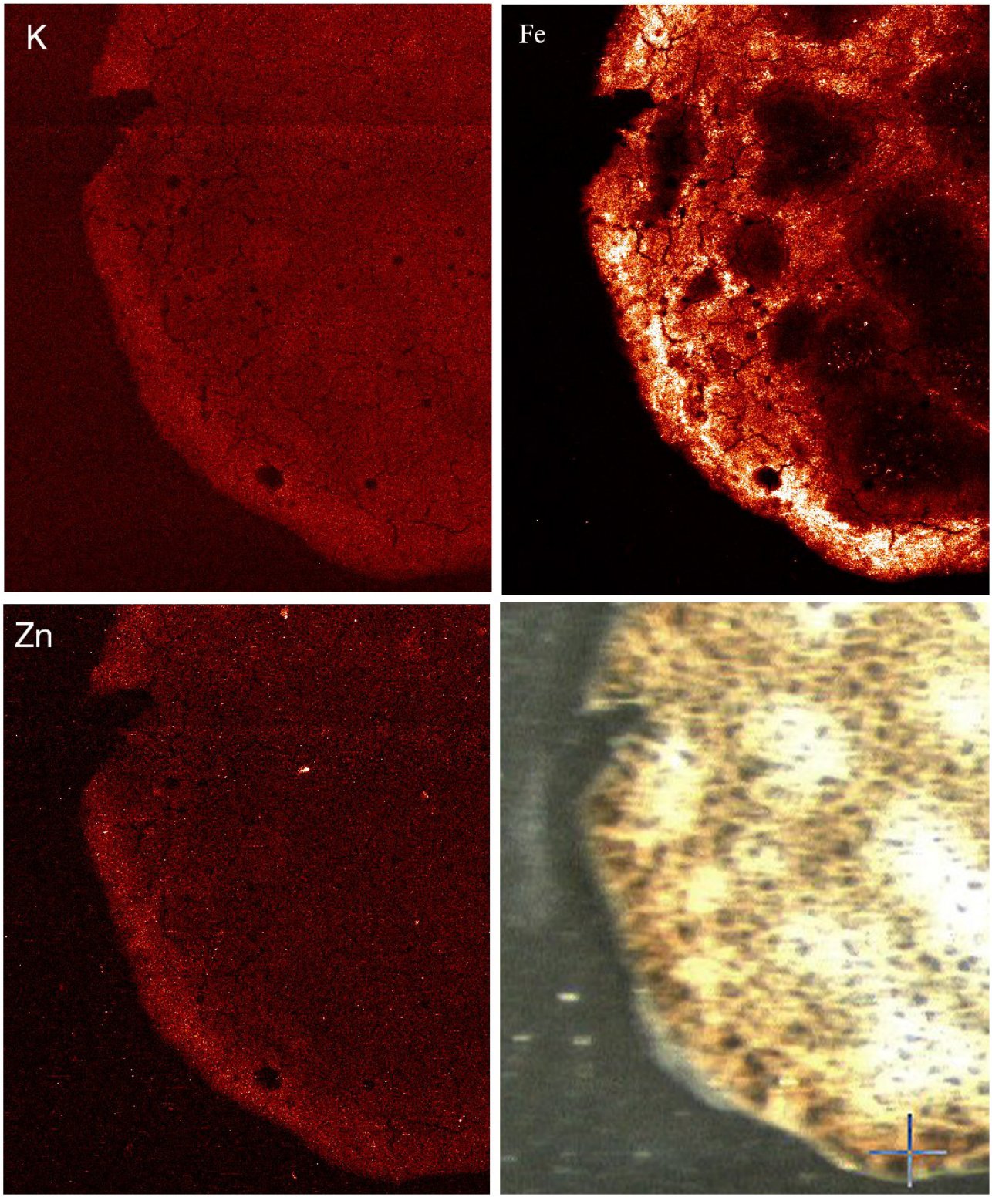


This is another example of a scan done at SSRF of a mouse spleen with the following parameters:

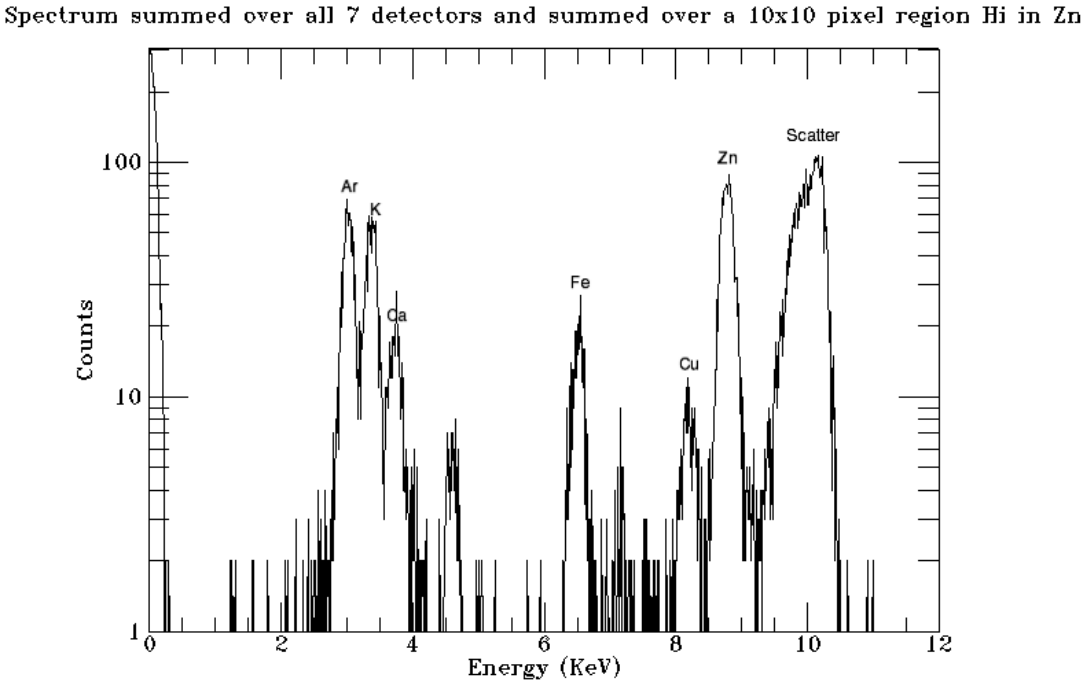
- 3x3 micron pixels.
- 530x647 pixel scan.

- 20 ms per pixel
- 7-element Si(Li) detector with 2 xMAP modules.
- Total scan time was 178 minutes

This is the image produced by summing over the counts in the channel regsions for K, Fe, and Zn. The image in the lower right is a visible light image from the sample microscope.



This spectrum of a 10x10 pixel region high in Zn in the above image. It was produced by reading the entire spectrum for 10x10 pixel region and then summing over all 100 pixels, and then summing over all 7 detectors.

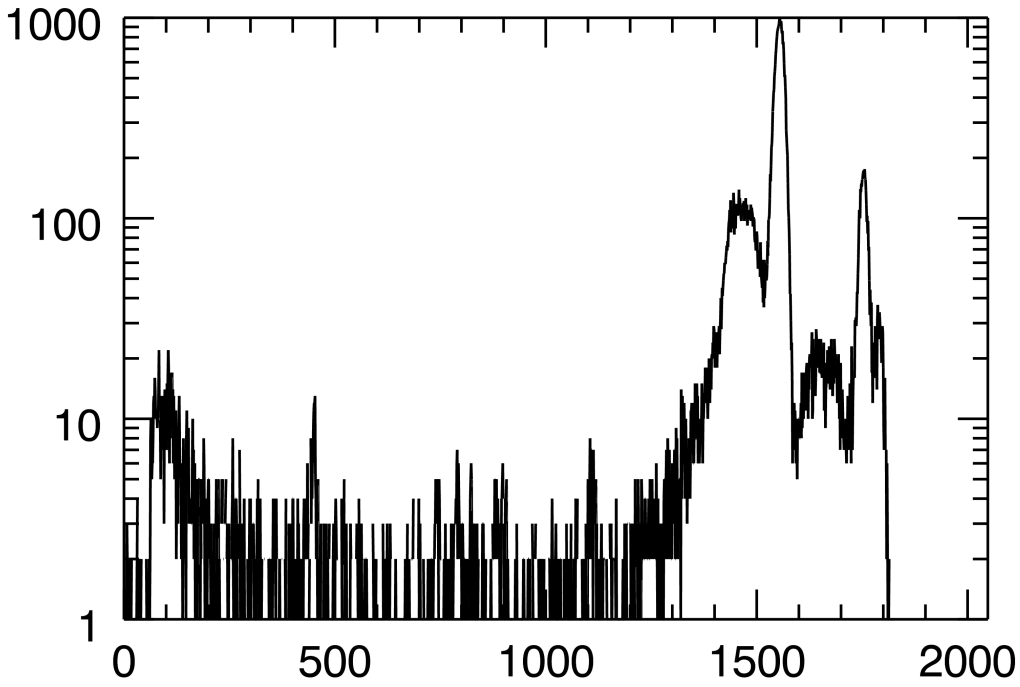


This is an example of decoding the buffers in IDL for List Sync mode data. It computes and plots the histogram (spectrum) of all of the events.

```
IDL> buff = read_nd_netcdf('list_mapping_sync_001.nc')
IDL> help, buff
BUFF            INT       = Array[1048576, 4]
IDL> d = decode_xmap_buffers(buff)
IDL> help, /structure, d
** Structure XMAPLISTDATA, 8 tags, length=32, data length=32:
   LISTMODE        LONG                 1
   PDATA           POINTER   <ptrheapvar17>
   PPIXELCLOCK     POINTER   <PtrHeapVar18>
   PNUMEVENTS      POINTER   <PtrHeapVar19>
   PREALTIME       POINTER   <PtrHeapVar20>
   PLIVETIME       POINTER   <PtrHeapVar21>
   PINPUTCOUNTS    POINTER   <PtrHeapVar22>
   POUTPUTCOUNTS   POINTER   <PtrHeapVar23>
IDL> help, *d.pData
<PtrHeapVar17>  INT       = Array[349525, 4]
IDL> help, *d.pPixelClock
<PtrHeapVar18>  LONG      = Array[349525, 4]
IDL> help, *d.pRealTime
<PtrHeapVar20>  FLOAT     = Array[16]
IDL> h = histogram((*d.pData) and 8191)
```

```
IDL> iplot, h, yrange=[1,1e3], /ylog
```

This is the histogram (spectrum) of all of the events for all detectors. Note that bits 13 and 14 (detector channel number 0-3) for each event are masked off.



Installing the EPICS DXP software

To install the EPICS DXP software first decide whether you want to build the EPICS DXP software from source code, or install the pre-built binaries. Most users will just download the pre-built binaries. The Windows binaries should run on almost any version of Windows. The Linux binaries are built with Redhat Fedora kernel 2.6.27 and gcc version 4.3.0. These binaries should run on many recent versions of Linux, but this has not been extensively tested.

Building from the source code requires downloading EPICS base and all of the required synApps components. To build from source code on Windows for the win32-x86 architecture requires Microsoft Visual Studio .NET 2003 or later, plus perl and make. To build from source code on Windows for the cygwin32-x86 architecture requires the gcc, g++, perl and make packages from Cygwin. It is beyond the scope of this document to describe how to build the source code. Consult other EPICS documentation for this.

The DXP software provides example IOC directories, iocBoot/iocSaturn, iocBoot/iocXMAP, iocBoot/iocMercury, and iocBoot/iocDXP2X. These create EPICS process variables with names like dxpSaturn:dxp1.PKTIM, where dxpSaturn is the "prefix" for the process variable names, dxp1 is the DXP record

name, and PKTIM is the field name. The default prefixes are dxpSaturn:, dxpXMAP:, dxpMercury, and dxp2X:. These prefixes would be OK for installations where there will be at most one IOC of a given type on the subnet. However, in many cases there will be the possibility of more than one DXP module running EPICS on the same subnet. If this is the case then it is essential that each one use a different prefix, because EPICS process variable names must be unique on a subnet. The following is how to give your IOC a unique prefix, and still be able to upgrade the EPICS software easily. It is recommended that you follow these instructions even if you don't have name conflicts on your subnet, so that files you edit are in a directory that will not be overwritten when you upgrade the EPICS software.

- Make a copy of the iocSaturn, iocXMAP, iocMercury, or iocDXP2X directory. Let's assume you have a Saturn and will make your prefix be APSSat1:, so a good name for the directory would be iocAPSSat1.
- Edit all files in that directory (including st.cmd, and START_IOC*), changing all occurances of dxpSaturn: to APSSat1:.
- If you have created any higher-level medm screens that load the medm screens in this package, you will need to edit them to pass the new prefix, APSSat1:
- The next time you unpack a new version of the EPICS DXP software it will overwrite the iocSaturn directory. However, if you have made your own new directory, APSSat1/, that will not be modified.
- For the multi-element systems (iocXMAP, iocMercury, iocDXP2X) the files to be edited include, for example, 4element.cmd, 4element.substitutions, and START_EPICS.

The EPICS DXP application uses the EPICS save/restore facility. This means that all of the important parameters that you might change when running the DXP software are saved in files in the subdirectory called autosave/ under your IOC directory. These parameters include the peaking time, the update rates for displays and many other parameters. The next time EPICS is started it will restore these values automatically from the file called autosave/auto_settings.sav. On multi-element systems the files are called auto_settings4.sav, or auto_settings16.sav, etc. It is a good idea to make copies of this file from time to time so that you can get back to old settings if the file is lost or corrupted.

The DXP IOC application and EPICS clients both need to be able to start the EPICS caRepeater application. This application is built as part of EPICS base. If you are installing the Linux or Windows prebuilt versions of the DXP software you can obtain caRepeater as part of the EPICS WIN32 binaries or EPICS Linux binaries from our Web site. Unpack these directories into a directory on your computer, and put that directory into your PATH environment variable. That way EPICS will be able to find caRepeater. It will also provide many useful EPICS shell utilities, such as caput, caget, camonitor, etc. The IDL ezcaIDL.dll and ezcaIDL.so shareable libraries are also in that distribution.

Installing the DXP software on Windows

To install the EPICS DXP software with a Saturn, Mercury, or xMAP on a Windows PC do the following:

- Install the Windows Port IO Driver from Scientific Software Tools. This is a software driver that lets Windows applications communicate with I/O ports, including the Enhanced Parallel Port. Although this is only needed to communicate with the EPP port, the driver must be installed even if the EPP port will not be used, because the EPICS dxpApp application is linked with that DLL. The driver (port95NT.exe and dlportio.sys) is also included in the handelSrc/ (source version) and bin/win32-x86 (pre-built binary version) directories in the DXP distribution. It can also be found in the Handel source code distribution which is available through the XIA software downloads Web site. The driver is found in the redist/drivers/usb1 directory.
- To use the parallel port (EPP) interface on older Saturns and SII Vortex units:
    - ♦ Configure the parallel port to be in EPP mode. This requires entering the BIOS setup screen on

the computer before the operating system boots. The menus will differ from one computer to another, but it is necessary to set the parallel port to EPP mode. Other modes will not work.

- To use the USB 1.0 interface with the Saturn:
  - Install the ProSpect from XIA. This will install the required Windows driver for the USB 1.0 Saturn. The driver (ezusb.sys, xiausb.inf) is also included in the handelSrc/ (source version) and bin/win32-x86 (pre-built binary version) directories in the DXP distribution. The driver can also be found in the Handel source code distribution which is available through the XIA software downloads Web site. The driver is found in the redist/drivers/usb1 directory.
- To use the USB 2.0 interface with the Saturn or Mercury:
  - Install the ProSpect from XIA. This will install the required Windows EZ-USB driver for the USB 2.0 Saturn. The driver (cyusb.sys, cyusbme.sys, xia_usb2.inf) is also included in the handelSrc/ (source version) and bin/win32-x86 (pre-built binary version) directories in the DXP distribution. The driver can also be found in the Handel source code distribution which is available through the XIA software downloads Web site. The driver is found in the redist/drivers/usb2 directory.
- For an xMAP system do the following:
  - Install the PCI/PXI converter from National Instruments.
  - Install the National Instruments driver software.
  - Install the latest version of the xManager software from XIA. This will install the Plx driver that is used to communicate with the xMAP modules. It will also run a Configuration Wizard that will create an initial .ini file with the correct PCI bus and slot addresses for your system. You can copy that file to the iocXMAP directory or edit one of the .ini files there that most closely matches your system configuration (xmap4.ini, xmap8.ini, etc.). It is useful to have xManager available on the computer to compare with the EPICS software. The driver (Plx9054.sys, xia9054.inf) is also included in the handelSrc/ (source version) and bin/win32-x86 (pre-built binary version) directories in the DXP distribution.
- Chose whether to use the Cygwin (cygwin-x86) or native Windows (win32-x86) version of the EPICS software. The main reason to use Cygwin is to run the saveData utility, which will save EPICS scan data to disk. This utility does not currently run under the native Windows version because it lacks the Sun RPC library.
- If using Cygwin then install the basic Cygwin package. Cygwin is a public domain package that provides Unix-like programming libraries and commands on Windows. When using the Cygwin install program use all of the default settings, which will install just the basic package into C:\Cywgin.
- If you want to run the medm display program on the Windows PC, which is recommended in most cases, you need to install Exceed. Exceed is a commercial X-Windows package from Hummingbird. After installing Exceed you need to install the EPICS Win32 Extensions, which contain medm. Note that medm works with some non-commercial versions of X windows servers for Windows, but Exceed is guaranteed to work.
- Download the latest standalone release of the EPICS DXP software, containing Cygwin and native Windows binaries.
- Unpack that distribution into a directory such as C:\EPICS or C:\Program Files\EPICS. The distribution file, dxpStandlone_XXX.tgz can be unpacked using WinZip, or with the gunzip and tar utilities that come with Cygwin. To use the Cygwin tools:

```
$ cd /cygdrive/c/epics         # Or wherever you have chosen to put the EPICS software
$ tar xzvf dxpStandalone_3-0.tgz    # Unpack the tar file.
```

- Make sure that the .bat files in iocBoot/ioc*/ have execute permission. This can be done by running the Cygwin bash shell and typing

```
$ cd iocBoot/iocSaturn
$ chmod +x *.bat
```

This is necessary because these files may not have this permission, depending on how they were unpacked from the distribution.

- Copy all of the medm .adl files into a single directory. This is simpler than defining EPICS_DISPLAY_PATH to point to all of the required directories. For example, if you decide to put the .adl files in C:\epics_adls, and if you unpacked the dxp tar file distribution into C:\epics, then type the following commands at the Cygwin bash shell prompt:

```
$ mkdir /cygdrive/c/epics_adls
$ find /cygdrive/c/epics -name '*.adl' -exec cp -f -p -v {} /cygdrive/c/epics_adls \;
```

Define the environment variable EPICS_DISPLAY_PATH to point to C:\epics_adls. For the Windows shell use the Windows Control Panel/System/Advanced/Environment Variables. For the Cygwin shell edit your .bashrc file.

- If you look at that batch file, you will see a line that temporarily sets the environment variable PATH to C:\cygwin\bin. You may want to add this directory permanently to your Windows path for Windows shells. Again, use the Windows Control Panel/System/Advanced/Environment Variables. Modify the definition according to where you have installed Cygwin. Note that the PATH will be set to automatically include that directory when running the Cygwin bash shell.
- If you installed pre-built binaries, rather than building from source, then edit the envPaths file in iocBoot/iocSaturn. Change the paths to the locations of the directories on your system. Don't worry about the path for directories that don't exist, like SNCSEQ, EPICS_BASE, etc.

The DXP software uses the EPICS areaDetector module for the file-saving plugins that are used in mapping modes. Some of these plugins use Windows DLLs. These DLLs are provided with the prebuilt version of the DXP software, in the areaDetector/bin/win32-x86 or cygwin-x86 directories. Windows needs to be able to find these DLLs when you run the DXP software. The easiest way to do this is to put the path to the DLLs in your Windows PATH environment variable. This is done in the example startup scripts in the iocBoot directories.

The XIA software is very slow when downloading the firmware files (.fdd files) to the hardware when the files reside on a remote file system. It is best to put the FDD files on a local file system, particularly when using an xMAP system with multiple xMAP modules.

There is a known problem with EPICS clients losing connections to a Cygwin IOC when they subscribe to a large number of array callbacks. This can happen with DXP application, since clients may subscribe to callbacks from many MCA records. This can affect any client, such as IDL, medm, the EPICS sscan record, Python, etc. It is a serious problem that appears to be a bug in Cygwin itself. Hopefully it will be tracked down and fixed in the future. If you do not need to use the saveData function in the DXP IOC itself, then you can work around this problem by using the win32-x86 version of the DXP software.

Installing the DXP software on Linux

To use the EPICS DXP software with a Saturn or Mercury on a Linux computer do the following:

- To use the USB 1.0 or USB 2.0 interface:
  - ♦ Install the latest version (0.1.12 or later) of libusb from SourceForge. This software must be installed using the root account. The version of libusb that comes with some Linux systems is older, and often will not work, so install this more recent version.
- Download the latest standalone release, of the EPICS DXP software, containing Linux binaries.

- Unpack that distribution into a directory such as /usr/local/epics. The distribution file, dxpStandalone_XXX.tgz can be unpacked using the Linux tar utility, e.g.:

```
tar xvzf dxpStandalone_3-0.tgz
```

- Copy all of the medm .adl files into a single directory. This is simpler than defining EPICS_DISPLAY_PATH to point to all of the required directories. For example, if you decide to put the .adl files in /home/epics/epics_adls, and if you unpacked the dxp tar file distribution into /home/epics/epics, then type the following commands at the shell prompt:

```
$ mkdir /home/epics/epics_adls
$ find /home/epics/epics -name '*.adl' -exec cp -f -p -v {} /home/epics/epics_adls \;
```

  Define the environment variable EPICS_DISPLAY_PATH to point to /home/epics/epics_adls. Do this by editing your .cshrc or .bashrc file.
- Access to the EPP I/O port on Linux requires root privilege. This can be done in any of following 3 ways:
  1. Prefered method. The EPICS DXP software on Linux contains a program called startWithIopl3. This program calls iopl(3) as root, and then reverts back to the non-root account to run dxpApp. NOTE: This method does not work on some versions of Linux, probably because of SELinux protections that prevent processes started with execv() from inheriting the iopl(3) permissions. To use this method the application startWithIopl3 must be installed as suid root. Do this as follows:

     ```
     > cd bin/linux-x86
     > su root
      (password)
     > chmod +s startWithIopl3
     > exit
     ```

     The dxpApp application can then be run without root privilege as follows:

     ```
     > cd iocBoot/iocSaturn
     > ../../bin/linux-x86/startWithIopl3 ../../bin/linux-x86/dxpApp st.cmd
     ```

     You can also copy startWithIopl3 to a directory like /usr/local/bin or ~/bin that is in your PATH. That way it can be run without having to specify the path.
  2. Not as good. Install the dxpApp application as suid root. Do this as follows:

     ```
     > cd bin/linux-x86
     > su root
     (password)
     > chmod +s /bin/linux-x86/dxpApp
     > exit
     ```

     The dxpApp application can then be run without root priviledge as follows:

     ```
     > cd iocBoot/iocSaturn
     > ../../bin/linux-x86/dxpApp st.cmd
     ```

  3. Least desirable method. Run dxpApp as root:

     ```
     > cd iocBoot/iocSaturn
     > su root
     ```

```
(password)
> ../../bin/linux-x86/dxpApp st.cmd
or
> sudo ../../bin/linux-x86/dxpApp st.cmd
```

- USB devices on Linux are automatically created with read-only permission for non-root users by default. In order to run the dxpApp application without root privilege it is necessary to change the device permissions. Because these devices are created dynamically when the Saturn or Mercury is connected, this cannot just be done once statically. Rather it requires using the "hotplug" or "udev" facilities on Linux to have the device permissions set correctly each time the device connects. More recent Linux kernels use the "udev" facility, older kernels use the "hotplug" facility. I do not know exactly which kernel version the switch to udev was done, but I do know from my systems that 2.6.9 uses hotplug while 2.6.22 uses udev. If the directory /etc/hotplug exists then the system is presumably using hotplug. In that case the directory /dev/bus/usb will probably not exist, only /proc/bus/usb will exist.
  Here is a recipe for older systems using hotplug.
  1. Add the following lines to the file /etc/hotplug/usb.usermap

     ```
     # XIA Saturn
     usbsaturn  0x0003  0x10e9  0x0700  0x0000  0x0000  0x00  0x00  0x00  0x00  0x00  0x00  0x00000
     usbsaturn  0x0003  0x10e9  0x0701  0x0000  0x0000  0x00  0x00  0x00  0x00  0x00  0x00  0x00000
     usbsaturn  0x0003  0x10e9  0x0702  0x0000  0x0000  0x00  0x00  0x00  0x00  0x00  0x00  0x00000
     usbsaturn  0x0003  0x10e9  0x0703  0x0000  0x0000  0x00  0x00  0x00  0x00  0x00  0x00  0x00000
     ```

     These lines instruct the hotplug facility to run the script /etc/hotplug/usb/usbsaturn whenever the Saturn or Mercury is added to the system. 10e9 is the vendor ID for XIA. 0700 and 0701 are the product IDs for the USB 1.1 and USB 2.0 versions of the Saturn. 0702 and 0703 are the product IDs for the Mercury and Mercury4.
  2. Create the file /etc/hotplug/usb/usbsaturn containing the following lines:

     ```
     #!/bin/bash

     if [ "${ACTION}" = "add" ] && [ -f "${DEVICE}" ]
     then
             chmod 666 "${DEVICE}"
     fi
     ```

  This script tells hotplug to set the permissions on the XIA USB device to 666 (owner, group, and world read/write):

  ```
  [root@vincent usb]# ls -lt /proc/bus/usb/001/021
  -rw-rw-rw-  1 root root 134 Jan  8 12:20 /proc/bus/usb/001/021
  ```

  Here is a recipe for newer systems using udev.

  1. Create a file in /etc/udev/rules.d called, for example, "80-saturn.rules". Put the following lines in this file.

     ```
     SUBSYSTEM=="usb",ACTION=="add",ATTRS{idVendor}=="10e9",ATTRS{idProduct}=="0700",MODE="0666"
     SUBSYSTEM=="usb",ACTION=="add",ATTRS{idVendor}=="10e9",ATTRS{idProduct}=="0701",MODE="0666"
     SUBSYSTEM=="usb",ACTION=="add",ATTRS{idVendor}=="10e9",ATTRS{idProduct}=="0702",MODE="0666"
     SUBSYSTEM=="usb",ACTION=="add",ATTRS{idVendor}=="10e9",ATTRS{idProduct}=="0703",MODE="0666"
     ```

These rules instruct the udev facility to set the permissions on the USB device to 666 (owner, group and world read/write) for the Saturn or Mercury whenever it is added to the system. 10e9 is the vendor ID for XIA. 0700 and 0701 are the product IDs for the USB 1.1 and USB 2.0 versions of the Saturn. 0702 and 0703 are the product IDs for the Mercury and Mercury4. Note that the 10e9 ID is case sensitive!
Note that the Linux "udev" facility has been evolving quite rapidly. The above lines work on a relatively recent Linux kernel (2.6.27). On older kernels the following syntax was required:

```
SUBSYSTEM=="usb_device",ACTION=="add",SYSFS{idVendor}=="10e9",SYSFS{idProduct}=="0700",
SUBSYSTEM=="usb_device",ACTION=="add",SYSFS{idVendor}=="10e9",SYSFS{idProduct}=="0701",
SUBSYSTEM=="usb_device",ACTION=="add",SYSFS{idVendor}=="10e9",SYSFS{idProduct}=="0702",
SUBSYSTEM=="usb_device",ACTION=="add",SYSFS{idVendor}=="10e9",SYSFS{idProduct}=="0703",
```

In the older version the SUBSYSTEM is "usb_device" rather than "usb", and the SYSFS keyword rather than ATTRS is used.

2. Force the udevd daemon to reload its rules:

```
$ /sbin/udevcontrol reload_rules
```

These changes for udev should cause the Saturn or Mercury USB device to have the correct permissions:

```
baja:/etc/udev/rules.d>ls -lt /dev/bus/usb/005/021
crw-rw-rw- 1 root root 189, 532 2008-01-07 16:08 /dev/bus/usb/005/021
```

However, on some Linux versions libusb uses /proc/bus/usb by default, rather than /dev/bus/usb, so the permissions set by udev will not have the desired affect. This can be fixed by defining the environment variable USB_DEVFS_PATH to be /dev/bus/usb. In fact I now add the following command to the EPICS IOC startup script (st.cmd) on Linux when using USB, just before the xiaInit command:

```
# On Linux execute the following command so that libusb uses /dev/bus/usb
# as the file system for the USB device.
# On some Linux systems it uses /proc/bus/usb instead, but udev
# sets the permissions on /dev, not /proc.
epicsEnvSet USB_DEVFS_PATH /dev/bus/usb
```

This could obviously be done in the shell startup script instead if desired.

- Make sure that the script files in iocBoot/iocSaturn/ and iocBoot/iocMercury have execute permission. This can be done by typing

```
$ cd iocBoot/iocSaturn
$ chmod +x START_IOC*
```

This is necessary because these files may not have this permission, depending on how they were unpacked from the distribution.

- If you installed pre-built binaries, rather than building from source, then edit the envPaths file in iocBoot/iocSaturn or iocBoot/iocMercury. Change the paths to the locations of the directories on your system. Don't worry about the path for directories that don't exist, like SNCSEQ, EPICS_BASE, etc.

Installing the DXP software for the DXP2X

The DXP4C2X CAMAC module is supported under vxWorks. It works with the Kinetic Systems 3922/2922 VME to CAMAC adapter.

Running the EPICS DXP software

Running the Saturn

There are several things that should be done to run Saturn system under the EPICS software.

- Edit saturn.ini in the IOC directory. Uncomment to appropriate lines to select correct the firmware for the Saturn speed (20MHz or 40MHz) and pre-amp type (reset or RC). Uncomment the correct lines for the interface you are using (EPP, USB 1.0 or USB 2.0).
- Edit the saturn.ini to set the polarity, the pre-amp gain, and the time after reset (for reset pre-amps) or the RC time constant (for RC pre-amps). Consult the Saturn User's Manual for information on how to determine and set these parameters. The saturn.ini file will contain lines like the following:

```
type_value = 10.
channel0_gain = 1.7
channel0_polarity = +
```

  - The type_value is the transient settling time after a reset in microseconds for reset pre-amps. It is the RC time constant in microseconds for RC pre-amps. 10 microseconds is a reasonable value for both of these to start with.
  - The gain is specified in mV/keV, and is used so that the energy units in the DXP software are correct. Most pre-amps are in the 1-4 mV/keV range. The best way to set this value is to set the EMAX parameter (energy of last channel) in EPICS, and see how well it agrees with reality when you calibrate the spectrum with a known source. Then iteratively edit the saturn.ini file and restart EPICS until the actual EMAX matches the requested one. Getting it to within a few percent is fine, since you will do accurate calibration of the EPICS MCA spectra when you collect data.
  - The polarity can be "+" or "-". A positive polarity means that an x-ray pulse produces a voltage step with a rising edge.
- Make sure that the switch inside the Saturn is set for the correct pre-amp type. The switch is labeled "RAMP" for reset pre-amps and "OFFSET" for RC pre-amps.
- Connect the parallel port or USB cable from the Saturn to the PC, and turn on the Saturn.
- Under Windows, start the EPICS IOC and medm by running the batch file iocBoot/iocSaturn/START_IOC.bat. This can be done by double clicking on the icon for this file. You should see the EPICS IOC commands in a Windows command shell, and you should hear clicking sounds from the Saturn. If everything works correctly, you can then begin to collect and display spectra.
- Under Linux start the EPICS IOC and medm by running the script iocBoot/iocSaturn/START_IOC. This can be done by typing:

```
> cd iocBoot/iocSaturn
> ./START_IOC
```

  You may need to edit the START_IOC script depending on how you chose to solve the root priviledge problem, and whether startWithIopl3 is in your path. You should see the EPICS IOC commands, and you should hear clicking sounds from the Saturn. If everything works correctly, you can then begin to collect

and display spectra.

Running the xMAP

There are several things that should be done to run xMAP system under the EPICS software.

- There are startup scripts and template files for systems with 4 or 16 channels (1 or 4 xMAP modules). If you have a different number of channels you will need to create new files.
- You can manually start the software by doing the following in the Cygwin bash shell:

```
cd iocBoot/iocXMAP  # Or the new directory you created
../../bin/cygin-x86/dxpApp.exe 16element.cmd  # Or 4element.cmd, etc.
```

- You can also start the EPICS IOC and medm by running the batch file iocBoot/iocXMAP/START_IOC_Cygwin.bat or START_IOC_WIN32.bat. This can be done by double clicking on the icon for this file. You should see the EPICS IOC commands in a Windows command shell, and you should hear clicking sounds from the xMAPS. If everything works correctly, you can then begin to collect and display spectra. You may need to edit these batch files to set the prefix for your IOC, the location of your medm adl files, etc.
- You can do scans and save complete spectra with the EPICS sscan and saveData facilities.

Running the Mercury

The Mercury can be run under Linux (linux-x86 or linux-x86_64) or Windows (cygwin-x86 or win32). As with the Saturn and xMAP described above there is an example mercury4.ini, and there are example startup scripts (START_IOC for Linux, and START_IOC_Cygwin and START_IOC_WIN32 for Windows).

Running the DXP2X

The DXP2X is run under vxWorks. There is an example IOC for the DXP2X with startup ini files and scripts for 4 and 16 element systems. The ini file will need to be edited for the CAMAC address of the modules in your system.

Performance

Normal MCA Spectra Mapping Mode

The following measurements were done in normal MCA Spectra mode with R3-0 of the dxp module to determine the performance of the DXP software in rapidly collecting complete spectra in a scan. The tests were done with the following conditions:

- Both cygwin-x86 and win32-x86 architectures on Windows. However, spectra were only saved to disk when testing with the cygwin-x86 architecture, because win32-x86 does not currently support the saveData software.
- 2048 channel spectra
- 0.01 second acquisition time, in order to attain real data but with minimal overhead.
- EPICS scan records.
    - The inner scan was the scanH record, which had its detector trigger configured to the EraseStart record. Its detectors were configured to collect spectra from the MCA records. The Saturn collected 1 MCA spectrum at each scan point, the xMAP, Mercury, and DXP2X collected 4 or 16

spectra at each scan point.

- The outer scan was the scan1 record. It had no positioner drive PV to minimize overhead. The detector trigger was scanH.EXSC. Its positioner readback was "time", which is how the time to execute the scan was measured.

- The scan fields of the MCA status, MCA read, and DXP read records were Passive to minimize overhead. The poller thread time was .01 seconds on the Saturn and DXP2X, .005 seconds on the Mercury, and .001 seconds on the xMAP. Callbacks caused the MCA records to be processed when acquisition was complete.
- saveData was used to save the scan data to a local hard disk, not across the network.
- 1000 scan points were collected. There were no positioner or detector delays in the scan records.
- The scan records were running on the same IOC as the DXP software.
- The system configuration for the xMAP is shown in this screen shot.

Normal MCA Spectra Mode Scanning Performance Measurements

XIA system	EPICS arch	Number of detectors	Seconds/1000 scan points	Scan points/second	Total spectra/second	Data rate (MB/second)
DXP4C2X	vxWorks-ppc604	4 (1 DXP4C2X)	217.0	4.6	18.4	0.15
DXP4C2X	vxWorks-ppc604	16 (4 DXP4C2X)	1250.0	0.8	12.8	0.10
Saturn (EPP)	cygwin-x86	1	32.5	30.8	30.8	0.25
Saturn (EPP)	win32-x86	1	28.0	35.7	35.7	0.29
Saturn (EPP)	linux-x86	1	29.8	33.6	33.6	0.27
Saturn (USB 1.0)	cygwin-x86	1	65.1	15.4	15.4	0.13
Saturn (USB 1.0)	win32-x86	1	67.1	14.9	14.9	0.12
Saturn (USB 1.0)	linux-x86	1	49.2	20.3	20.3	0.17
Saturn (USB 2.0)	cygwin-x86	1	27.3	36.6	36.6	0.30
Saturn (USB 2.0)	win32-x86	1	22.8	43.9	43.9	0.36
Saturn (USB 2.0)	linux-x86	1	21.9	45.7	45.7	0.37
Mercury	cygwin-x86	4	56.1	17.8	71.3	0.58
Mercury	win32-x86	4	52.2	19.2	76.6	0.63
Mercury	linux-x86	4	53.5	18.7	74.8	0.61
xMAP	cygwin-x86	4 (1 xMAP)	31.2	32.0	128.2	1.05
xMAP	win32-x86	4 (1 xMAP)	27.2	36.5	146.0	1.20
xMAP	cygwin-x86	16 (4 xMAPs)	122.2	8.2	130.9	1.07
xMAP	win32-x86	16 (4 xMAPs)	86.1	11.6	185.8	1.52

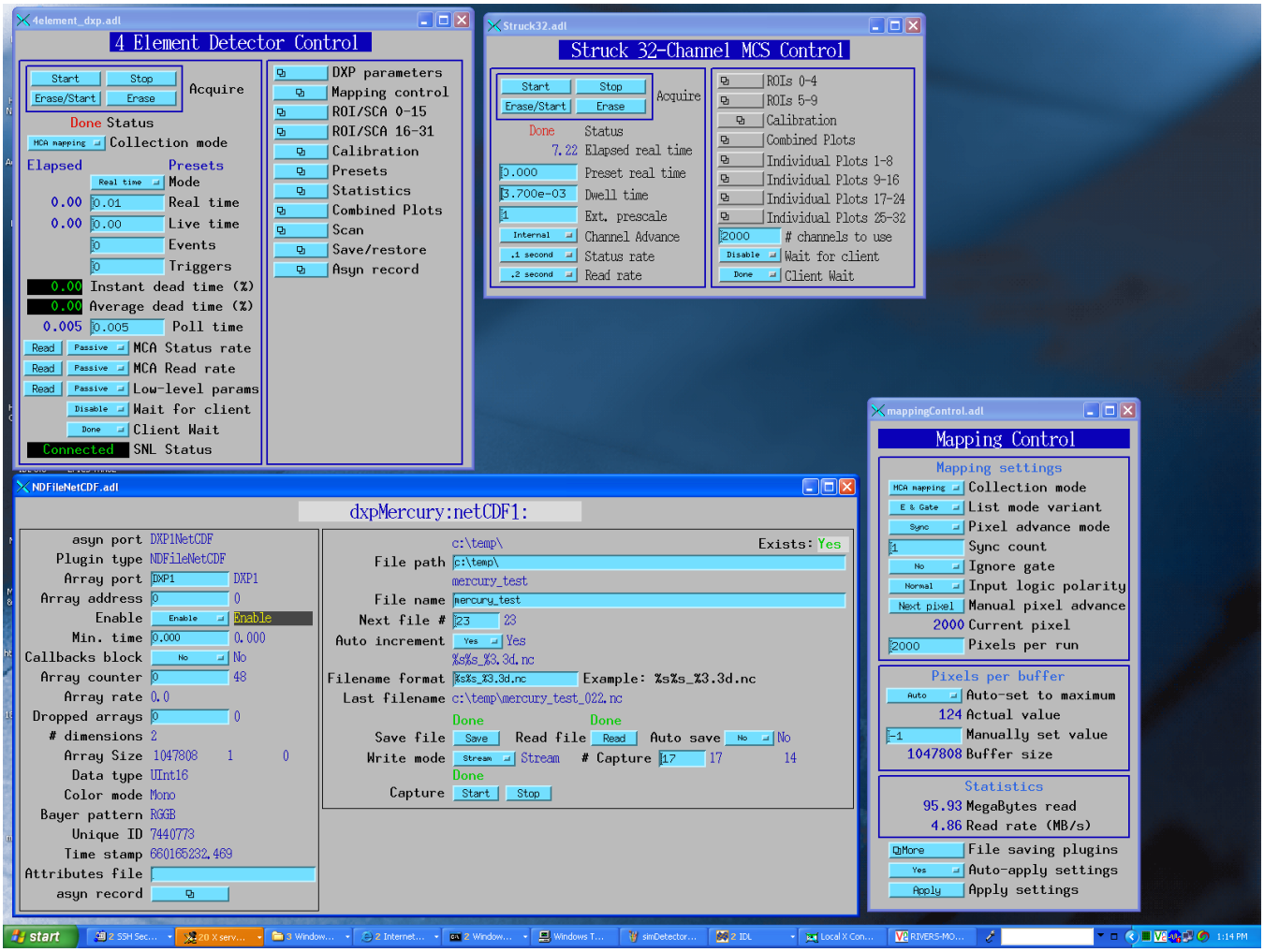
Mapping Mode

The following measurements were done in using the MCA Mapping and MCA Mapping modes with R3-0 of the dxp module to determine the performance of the DXP software in rapidly collecting data in a scan. The tests were done with the following conditions:

- Both cygwin-x86 and win32-x86 architectures on Windows.
- 2048 channel spectra in MCA Mapping mode
- 32 SCAs (ROIs) in SCA Mapping mode
- External Sync pixel advance mode
- The external sync signal was generated with an SIS3801 multichannel scaler. The SIS3801 was operated in internal channel advance mode. The dwell time was set to be the fastest that would work before errors

began, with 100 microsecond resolution, e.g. 3.6 ms per pixel worked and 3.5 ms per point failed.

- netCDF file saving plugin used to stream the data to a local disk.
- 2000 points were collected.
- The system configuration for the Mercury test is shown in this screen shot.



Mapping Modes Performance Measurements

XIA system	EPICS arch	Mapping mode	Number of detectors	Seconds/2000 scan points	Scan points/second	Total spectra or SCAs/second	Data rate (MB/second)
Mercury	cygwin-x86	MCA	4	7.4	270.2	1081.1	4.59
Mercury	win32-x86	MCA	4	7.4	270.2	1081.1	4.59
Mercury	linux-x86	MCA	4	5.2	384.6	1538.5	6.54
xMAP	cygwin-x86	MCA	4 (1 xMAP)	1.8	1111.1	4444.4	18.9
xMAP	win32-x86	MCA	4 (1 xMAP)	1.8	1111.1	4444.4	18.9
xMAP	cygwin-x86	MCA	16 (4 xMAPs)	7.4	270.3	4324.3	18.2

xMAP	win32-x86	MCA	16 (4 xMAPs)	7.0	285.7	4571.4	19.3
xMAP	cygwin-x86	SCA	4 (1 xMAP)	0.2	10000	1,280,000	5.0
xMAP	win32-x86	SCA	4 (1 xMAP)	0.2	10000	1,280,000	5.0
xMAP	cygwin-x86	SCA	16 (4 xMAPs)	0.2	10000	5,120,000	20.0
xMAP	win32-x86	SCA	16 (4 xMAPs)	0.2	10000	5,120,000	20.0

Suggestions and comments to: Mark Rivers : (rivers@cars.uchicago.edu)