

quadEM: EPICS Software for Fast Electrometers for Beam Position Monitors

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Outline

- Hardware
 - APS Electrometer (Steve Ross design) (old)
 - AH401 series from Trieste and CaenEls (new)
 - AH501 series from Trieste and CaenEls (new)
- EPICS software (complete rewrite)
 - Averaging analog input
 - Fast Time series
 - Fast feedback
- Demonstration with AH501

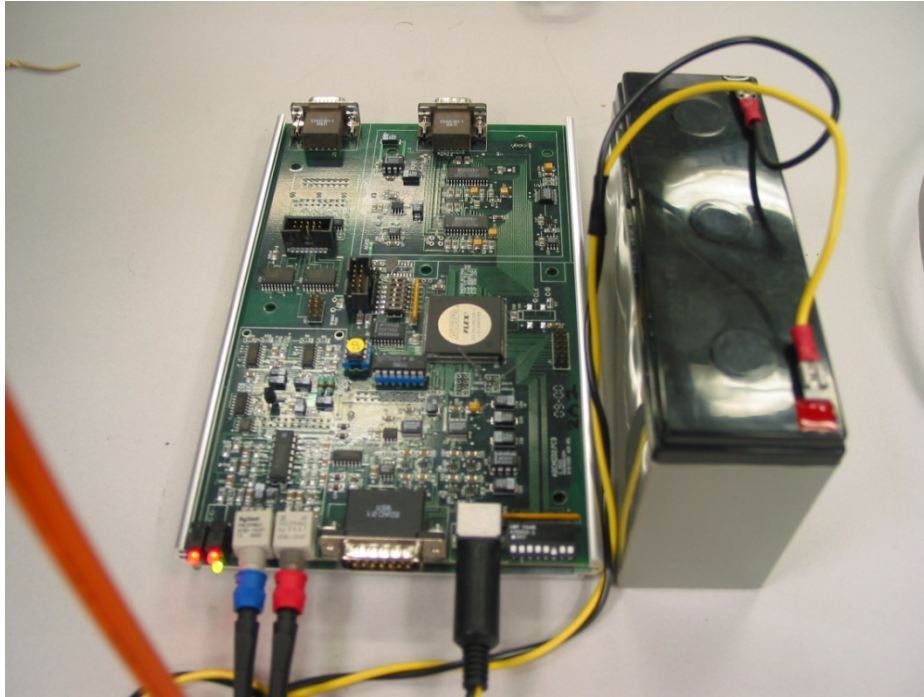
Hardware: Common Features

- 4-channel electrometers for measuring currents in the pA to mA range.
- Main application reading x-ray beam positions using 4 photodiodes or split ion chambers.
- Compact electrometer box, can be placed close to the position monitor hardware
 - Keep signal leads short!
- Outputs digital data at high-speed ($\sim 1-10$ kHz) over a remote interface (Ethernet or dedicated fiber)
- Digital interface allows reliable data transmission over long distances, for example from a BPM in an experiment station to a VME crate in the FOE, where feedback to a monochromator crystal can be implemented.
 - No analog signal runs over long distances!
- Replaces:
 - 4 SRS570 current amplifiers
 - 4 ADCs, or 4 V/F converters and 4 scaler channels

APS Electrometer (Steve Ross)

- Based on Texas Instruments Inc. (formerly Burr Brown Inc.) ddc112 chip
- Texas Instruments Inc. (formerly Burr Brown Inc.) ddc112 Selectable integration capacitors (2.51-17.6 pF, plus external=200pF-5000pF)
- Selectable integration time (0.615-131.1 ms)
- 2 separate channels (ping/pong).
 - One is integrating while other is reading out
 - Can each have separate external capacitors, i.e. gain)
- 20-bit resolution
- Maximum update rate 815 Hz.
- Remote box plus pair of VME cards
- No direct VME interrupts
 - TTL pulse on conversion can be used with Ip-Unidig for interrupt support.

APS Electrometer Hardware

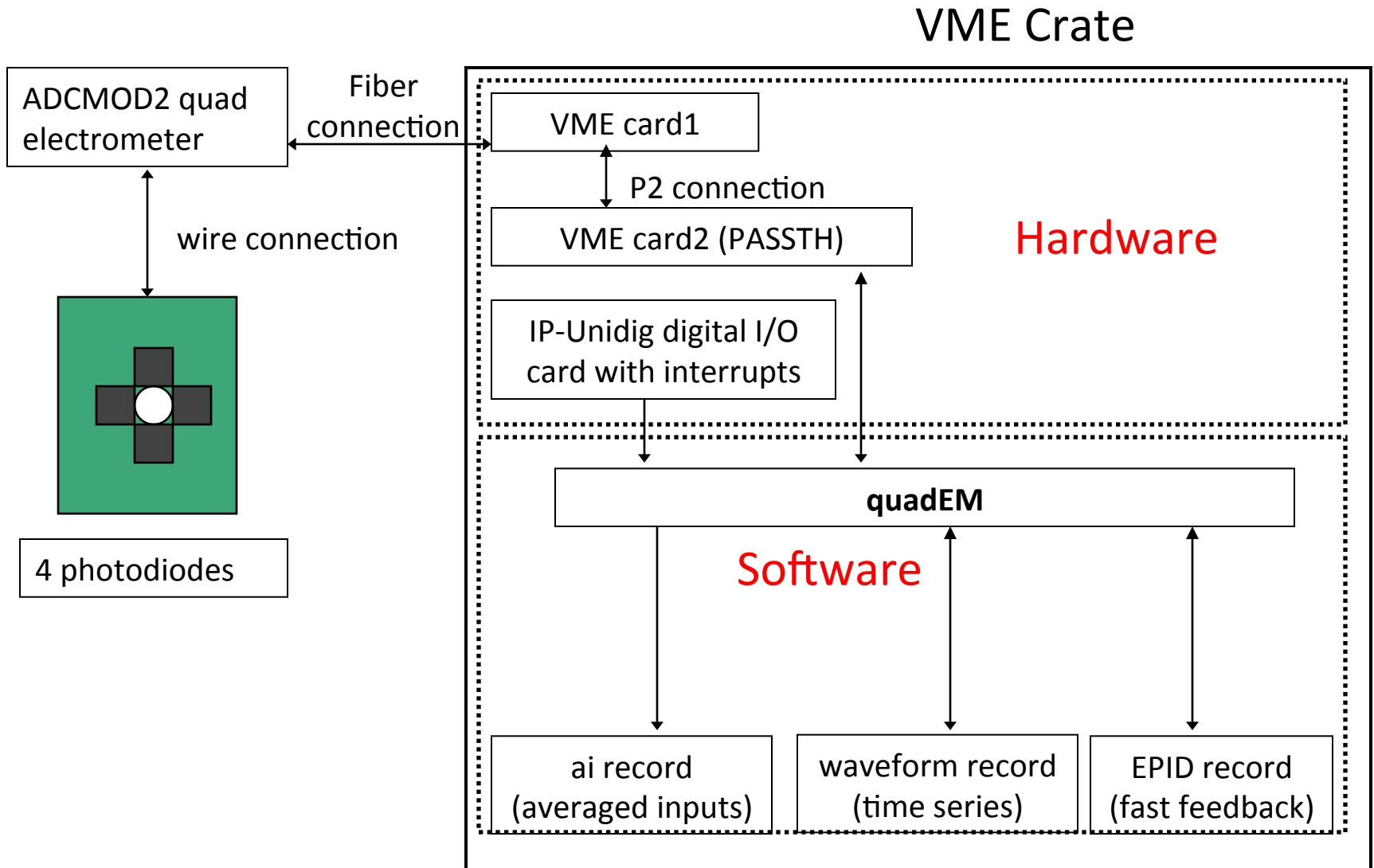


Remote ADC unit and
battery



VME boards

System Architecture



AH401 Series

- Based on selectable integration capacitor and integration time, like APS meter
- Ethernet interface, UDP or TCP
- Integration time 0.001 to 1.000 s
- Capacitance (charge) 50pC - 1800pC
- Ping-pong: use only 1 ADC channel, reduce noise, reduce bandwidth 2X
- Trigger input: convert only on hardware trigger

AH401 Series



AH401 Series

quadEM.adl

Quad Electrometer (quadEMTest:AH401B:)

Diode #	1	2	3	4
Current	20825	21543	20877	23758
Offset	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
	1&2	3&4	1&2&3&4	
Sum	42368	44190	84755	
Difference	718	3325		
Position	-143176719	-137107682		
Pos. Offset	<input type="text" value="0"/>	<input type="text" value="0"/>		
Pos. Scale	<input type="text" value="1000000"/>	<input type="text" value="1000000"/>		

Model AH401B

Sample time 1.0000e-03

Acquire

Range 1800 pC

Num. to average 1

Integration time 0.0010

Ping pong Yes

Trigger No

Reset

Read rate

Time series

Asyn record

AH501 Series

- Based on transconductance amplifier
- 3 ranges: $\pm 2.5\text{mA}$, $\pm 2.5\mu\text{A}$, $\pm 2.5\text{nA}$
- 16-bit or 24-bit data
- Programmable bias power supply (30V)
- Voltage monitor output proportional to current
- Programmable number of channels (1,2,4)
- Ethernet interface, UDP or TCP
- Update time: $38.4 \mu\text{sec} * \text{numChannels}$ (*2 for 24-bits):
 - 6.5 kHz for 4-channels, 16-bits
 - 3.2 kHz for 4-channels, 24-bits
 - 26.2 kHz for 1 channel, 16-bits
 - Data rates can burden slow VME crates – need to average

AH501 Series



AH501 Series

quadEM.adl

Quad Electrometer (quadEMTest:AH501:)

Diode #	1	2	3	4
Current	13377	19648	16168	-3051
Offset	-34	-97	-69	-677
	1&2	3&4	1&2&3&4	
Sum	33023	13118	46145	
Difference	6269	-19216		
Position	190	-1465		
Pos. Offset	0	0		
Pos. Scale	1000	1000		

Model AH501

Sample time 1.5360e-04

Acquire

Range +- 2.5 uA

Num. to average 1

Channels 4

Resolution 16 bits

Trigger No

Reset

Read rate .1 second

Time series

Asyn record

EPICS Software – quadEM Driver

- drvQuadEM
 - C++ base class, inherits from asynPortDriver
- drvAPS_EM
 - Derived class for APS electrometer
- drvAHxxx
 - Derived class for AH401 and AH501 series

EPICS Software – Common Controls

- Acquire – Start and stop acquisition
- Range (sensitivity)
- Reset (allows power-cycling device without rebooting IOC)
- Readings to Average (software)
 - Reduces CPU time when bandwidth is not needed
 - Reduces number of asynOctet read operations on AH401 and AH501 series
- Current offset (software)
- Position offset (software)
- Position scale (software)

EPICS Software – Hardware Specific Controls

- Integration Time (APS_EM, AH401)
- PingPong (APS_EM, AH401)
- Number of channels (AH501)
- Resolution (16 or 24 bits) (AH501)
- External Trigger (AH401, AH501)
- Bias Supply Enable and Voltage (AH501C, AH501D)

EPICS Software – Analog Input Records

- Uses asynInt32Average device support.
 - Driver calls device support each time there is a new reading (up to 26 kHz). Device support accumulates a total
 - Does an average when the record processes. Thus if record processes at 0.1Hz it can be the average of 10-2600 readings
- Can also use asynInt32 device support with Scan=I/O Intr to update ai record with every reading.
 - Likely to overwhelm the IOC if the update rate is > ~100 Hz.

AH501 Series

quadEM.adl

Quad Electrometer (quadEMTest:AH501:)

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	1&2	3&4	1&2&3&4	
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Model AH501

Sample time 1.5360e-04

Acquire

Range +- 2.5 uA

Num. to average 1

Channels 4

Resolution 16 bits

Trigger No

Reset

Read rate

Time series

Asyn record

EPICS Software – Time Series

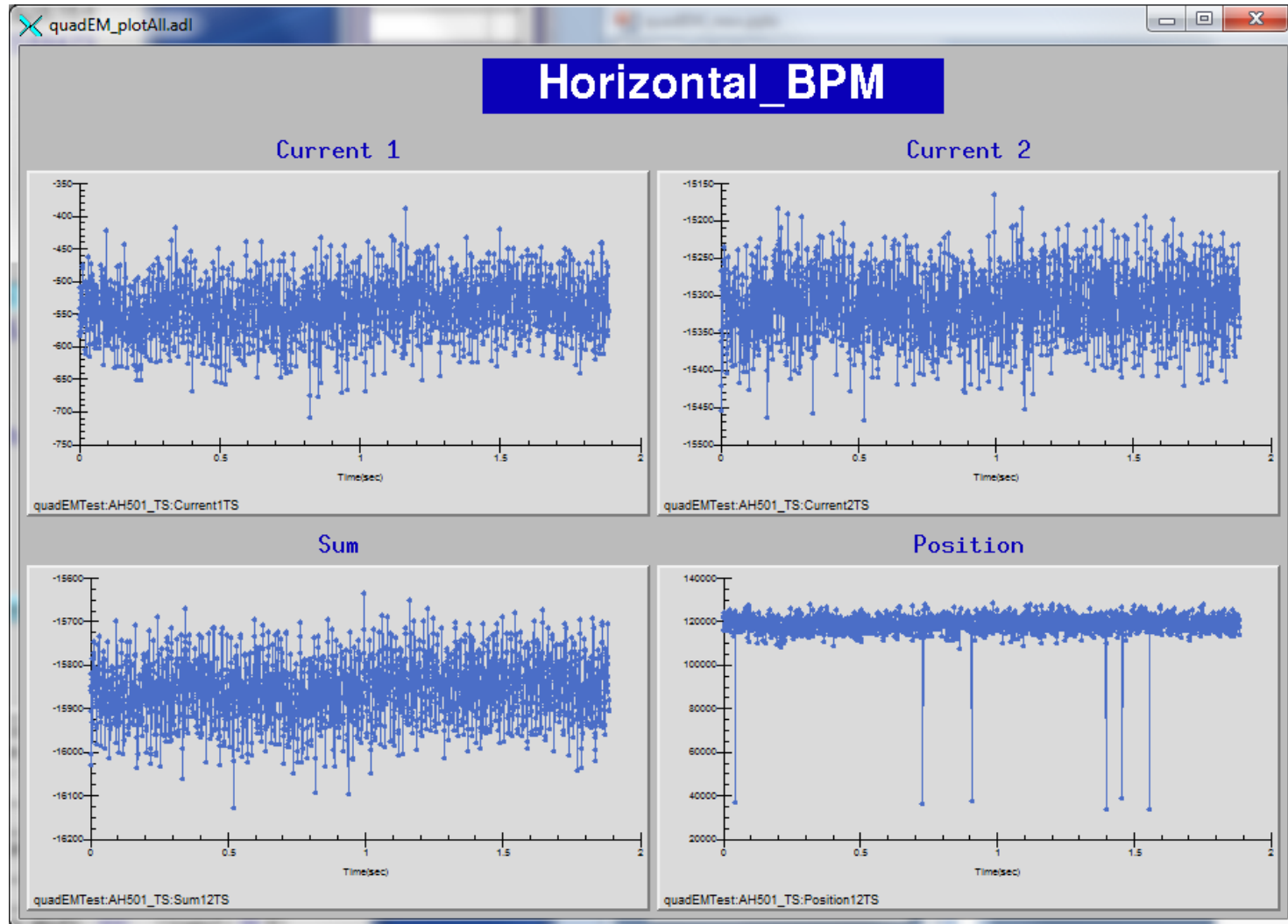
- Uses drvFastSweep driver in mca module
 - quadEM driver calls fast sweep driver each time there is a new reading (up to 26 kHz). Fast sweep driver puts point in a time series in waveform records
 - Fast sweep dwell time is constrained to be an integer multiple N of the quadEM sample time
 - If $N > 1$ then fast sweep driver does averaging
- SNL program does:
 - Processing each waveform record when acquisition completes or on periodic read
 - Computing FFTs (if enabled)
 - Autorestarting fast sweep (if enabled)

EPICS Software – Time Series

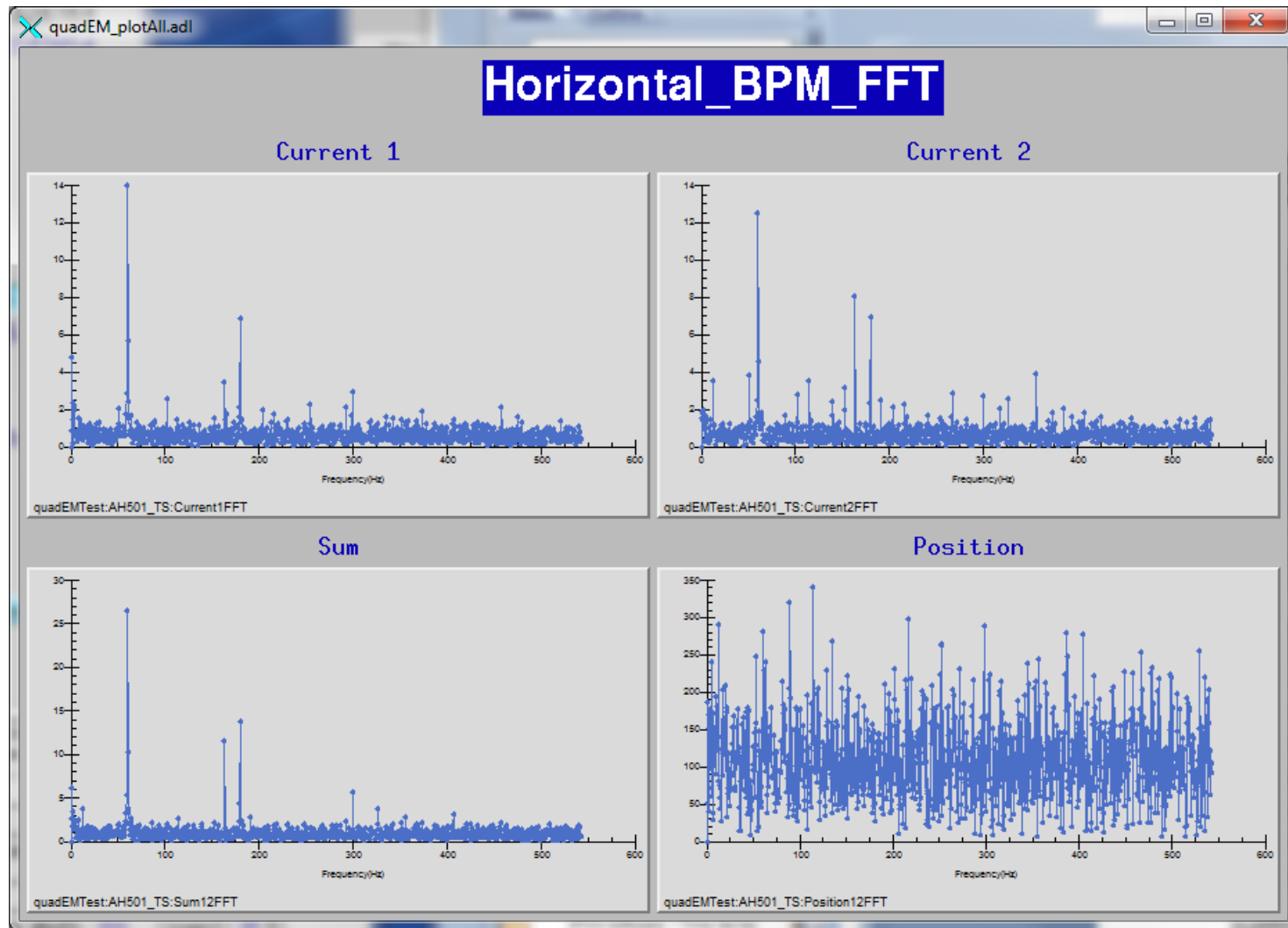
The screenshot shows a software window titled "quadEM Time Series Control" with a standard Windows-style title bar. The interface is divided into several sections:

- Acquire Section:** Contains four buttons: "Start", "Stop", "Erase/Start", and "Erase".
- Status Section:** Displays "Acquiring Status" in green. Below it are several numerical values and labels: "1.82 Elapsed time", "1.075e-03 Actual dwell time", "1.000e-03 Dwell time" (with a text input field), "0.000 Preset time" (with a text input field), "No Auto restart" (with a dropdown menu), "Yes Compute FFTs" (with a dropdown menu), "2048 Max. # of channels" (with a text input field), "2048 # channels to use" (with a text input field), and "1700 Current channel" (with a text input field).
- Time domain Section:** Contains three checkboxes: "Plots 1&2", "Plots 3&4", and "Single plots".
- Frequency domain Section:** Contains three checkboxes: "Plots 1&2", "Plots 3&4", and "Single plots".
- Control Section:** Contains a "Read rate" dropdown menu set to "1 second" and a "Read" button. Below it are three dropdown menus: "Wait for client" set to "Disable", "Client Wait" set to "Done", and "Asyn record" which is checked.
- SNL Status Section:** A black box with the word "Connected" in green text.

EPICS Software – Time Series

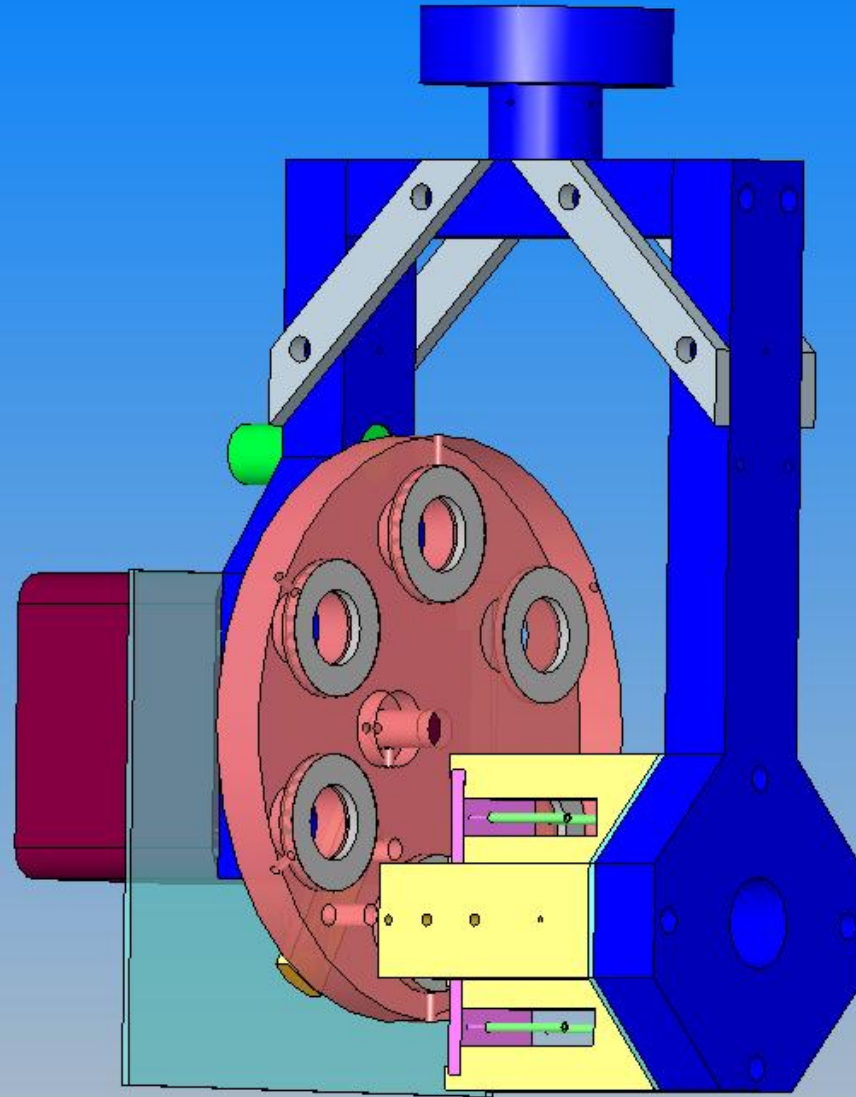


EPICS Software – FFT Power Spectra

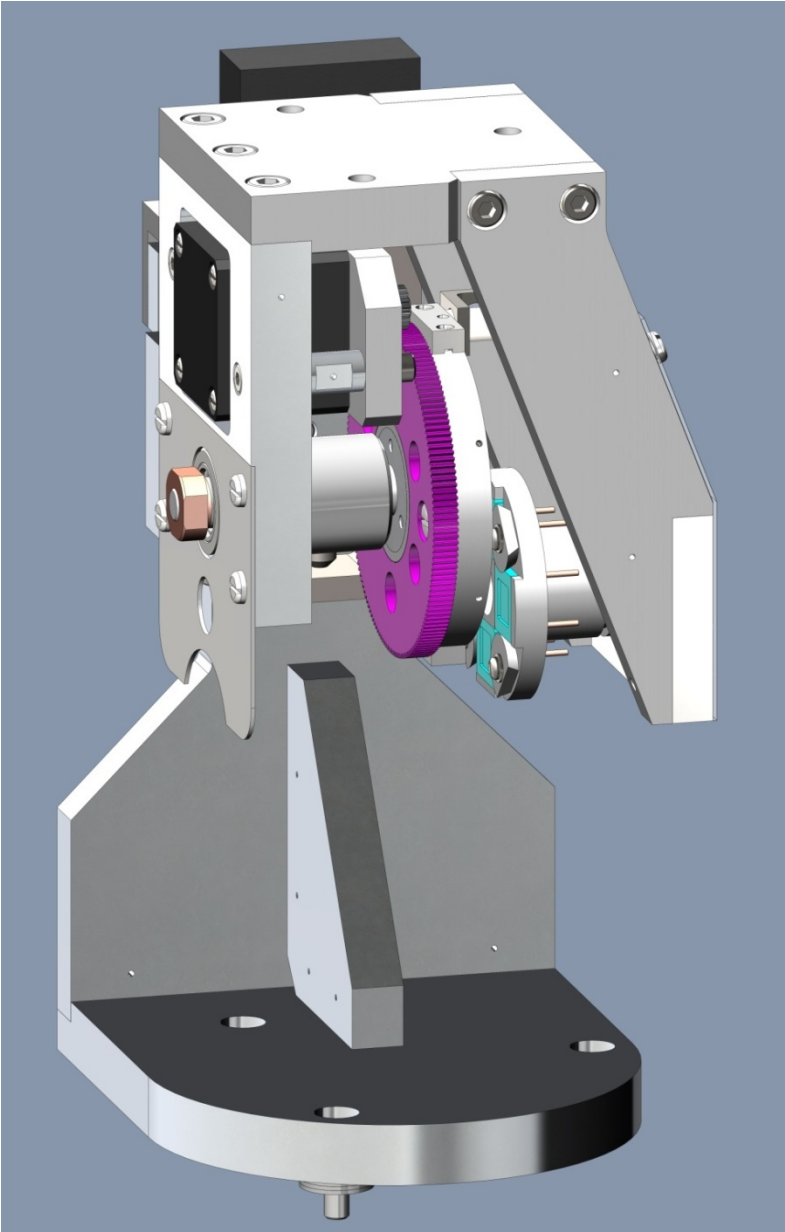


Demo

GSECARS Quad Foil Beam Position Monitor - Cartoon



GSECARS Quad Foil Beam Position Monitor – Solid Works Design



EPID record: An Enhanced EPICS Feedback Record

- Many applications for feedback on x-ray beamlines
 - Beam position stabilization from monochromators and mirrors
 - Temperature control
 - Pressure control
- Dedicated feedback controllers are expensive and relatively inflexible
- An EPICS record for performing feedback
 - Enhanced Proportional Integral Derivative (EPID)
 - Flexible and fast feedback under EPICS

“Slow” Feedback

- The EPID record has two kinds of device support.
- “Soft” device support allows the readback input and control output to be any EPICS process variables.
 - Very flexible
 - Any type of device can be used for input (analog to digital converter, RS-232, GPIB, scaler, etc.)
 - Any type of device can be used for output (digital to analog converter, RS-232, GPIB, etc.)
 - Can be reconfigured on the fly, changing the input and output process variables, feedback coefficients, etc.
 - If input is periodically scanned then limited to standard EPICS scan rates, typically 10 Hz maximum
 - If input is I/O Intr scanned then can run much faster, 100Hz or more
 - Overhead of record processing ultimately limits speed
 - Sufficient for many applications

“Fast” Feedback

- Input from any asyn driver that supports asynFloat64 with callbacks (e.g. callback on interrupt), e.g. quadEM driver
- Output to any driver that supports asynFloat64.
- Very fast
 - Up to 10 kHz feedback rate
- Feedback rate is constrained to be an integer multiple N of device sampling time
 - If $N > 1$ then averaging is done
- Feedback coefficients and feedback rate be reconfigured on the fly
- Record does not process each time feedback is performed
 - Very low overhead
- EPID record is typically processed periodically at 10Hz to provide snapshots of the feedback process

“Fast” Feedback

pid_control.adl

Mono_Pitch_feedback

Readback PV @quadEM1 8 DATA SCAN_PV

Control PV

Setpoint	Readback
0.000	22.782
Feedback	Update rate
On	.1 second

More

pid_parameters.adl

PID feedback parameters

KP	-0.020	P	-0.384
KI	600.000	I	1842.806
KD	0.000	D	0.000

Delta time 0.068

Error 19.200

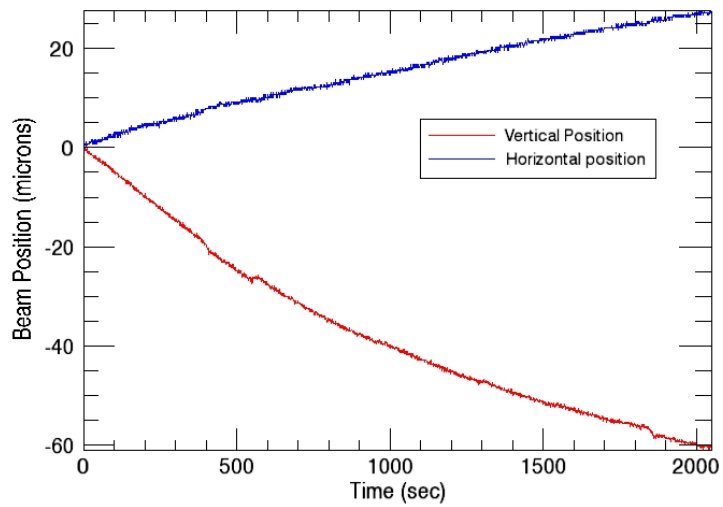
Output 1842.422

Low limit 0.000

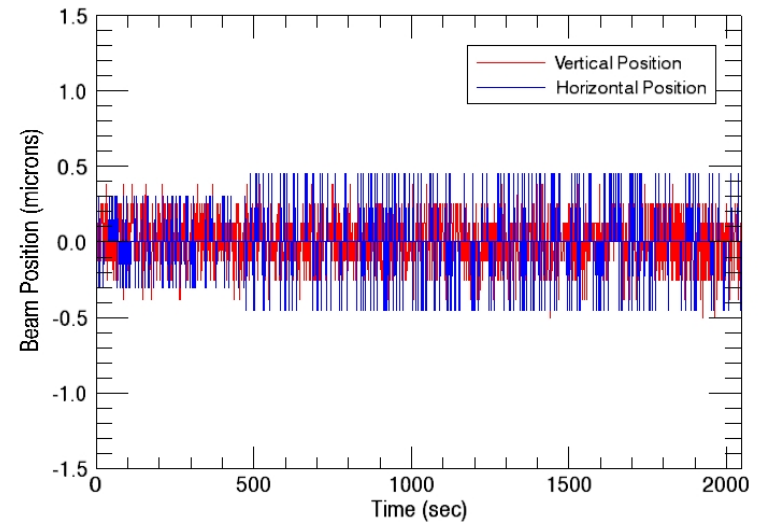
High limit 4095.000

Example Application: Monochromator Second Crystal Stabilization

Long-Term Drift, Feedback Off

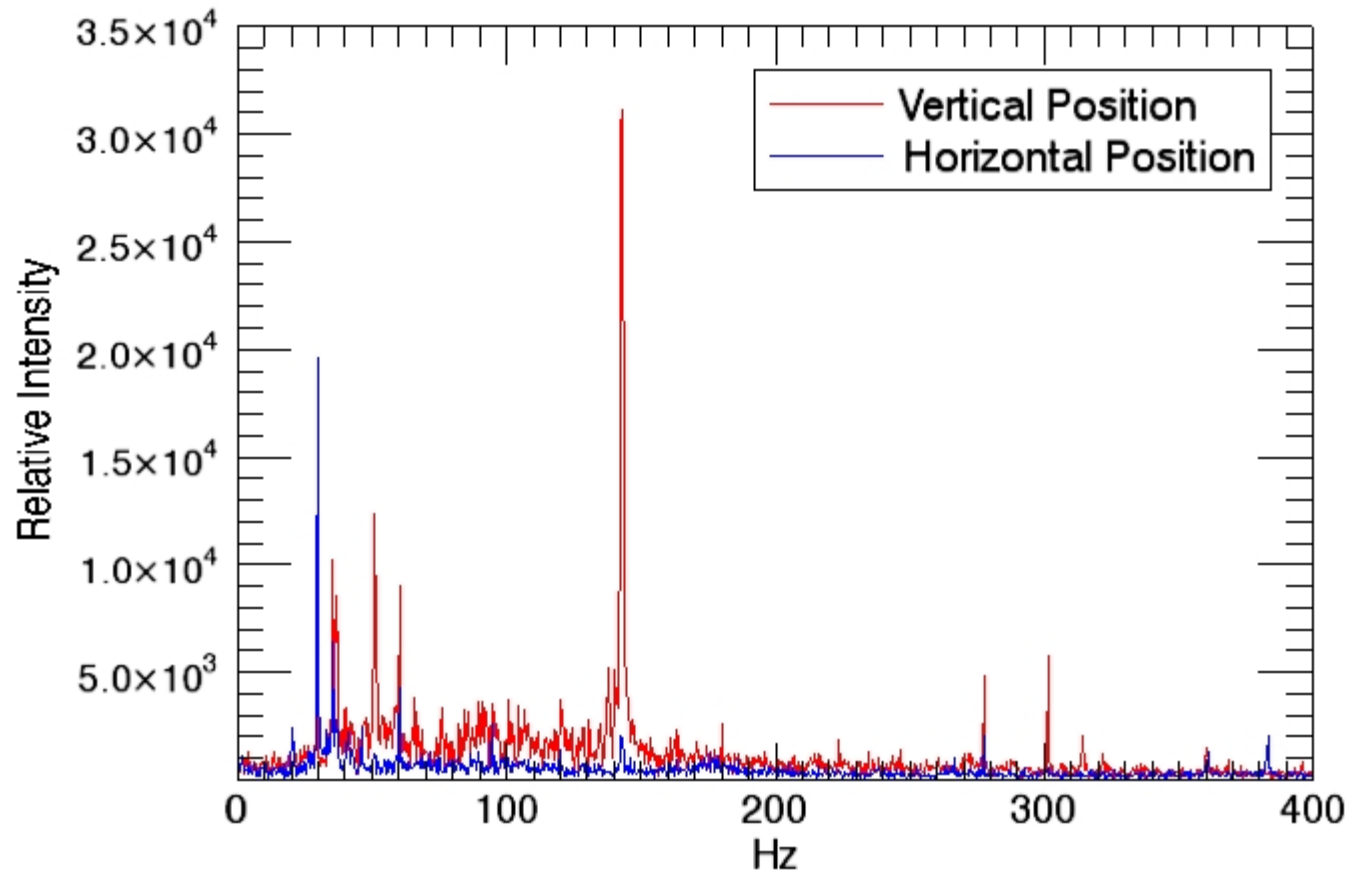


Long-Term Drift, Feedback On

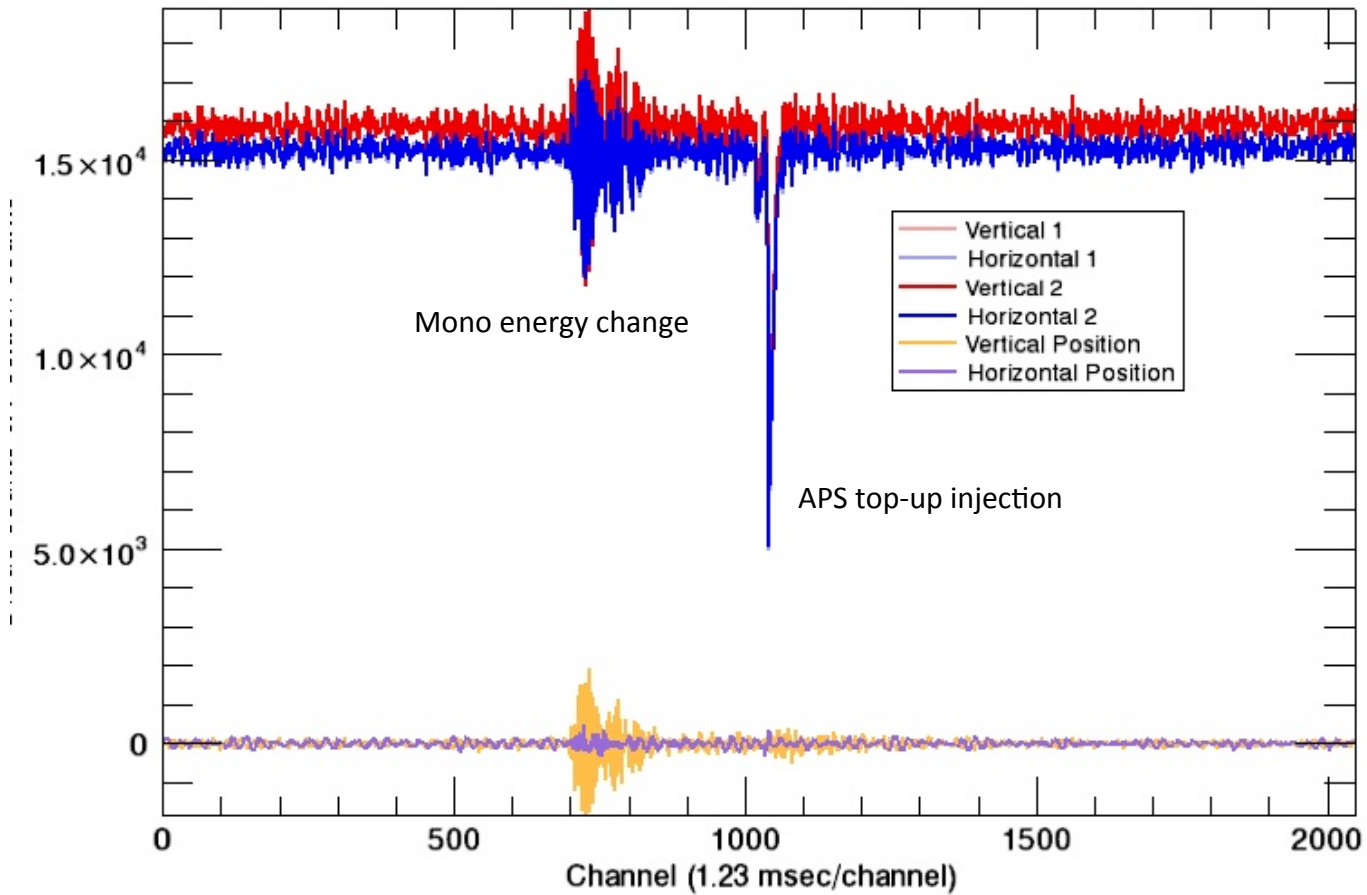


Example Application: Monochromator Position Frequency Spectrum

10 keV Position Frequency Analysis



Example Application: Monochromator Second Crystal Stabilization



Conclusions

- Fast electrometers permit:
 - High-frequency diagnostics of beam motion
 - High-frequency feedback to compensate for beam motion (or deliberate steering)
- EPICS quadEM software is part of synApps
 - Home page:
<http://cars9.uchicago.edu/software/epics/quadEM.html>
 - Documentation:
<http://cars9.uchicago.edu/software/epics/quadEMDoc.html>
 - Subversion repository
<https://subversion.xor.aps.anl.gov/synApps/quadEM/>

Thanks for your attention!