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

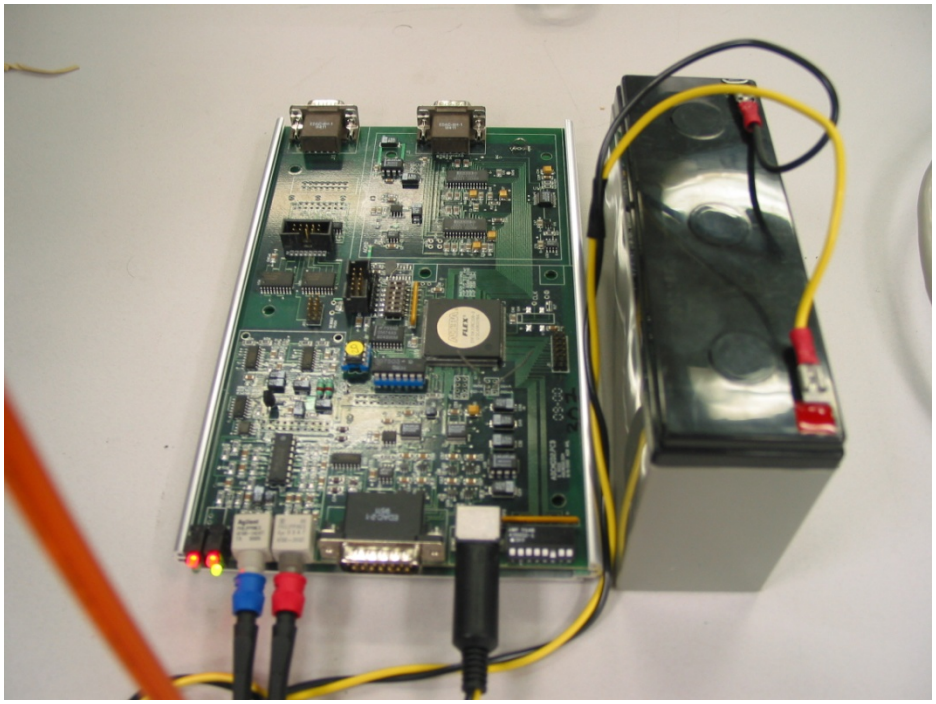
Hardware: Common Features

- 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 (~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.

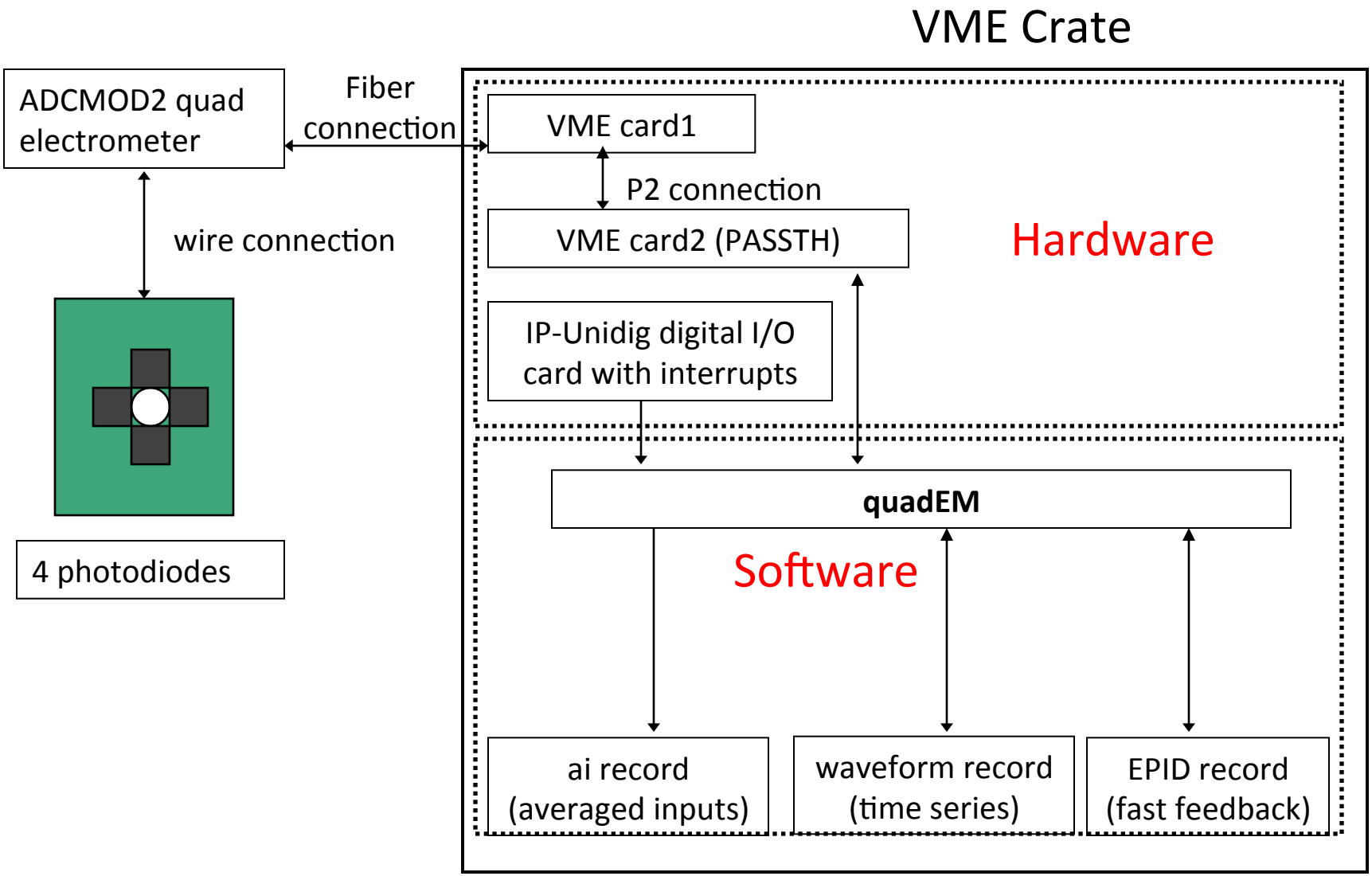
APS Electrometer Hardware



Remote ADC unit and battery

VME boards

System Architecture

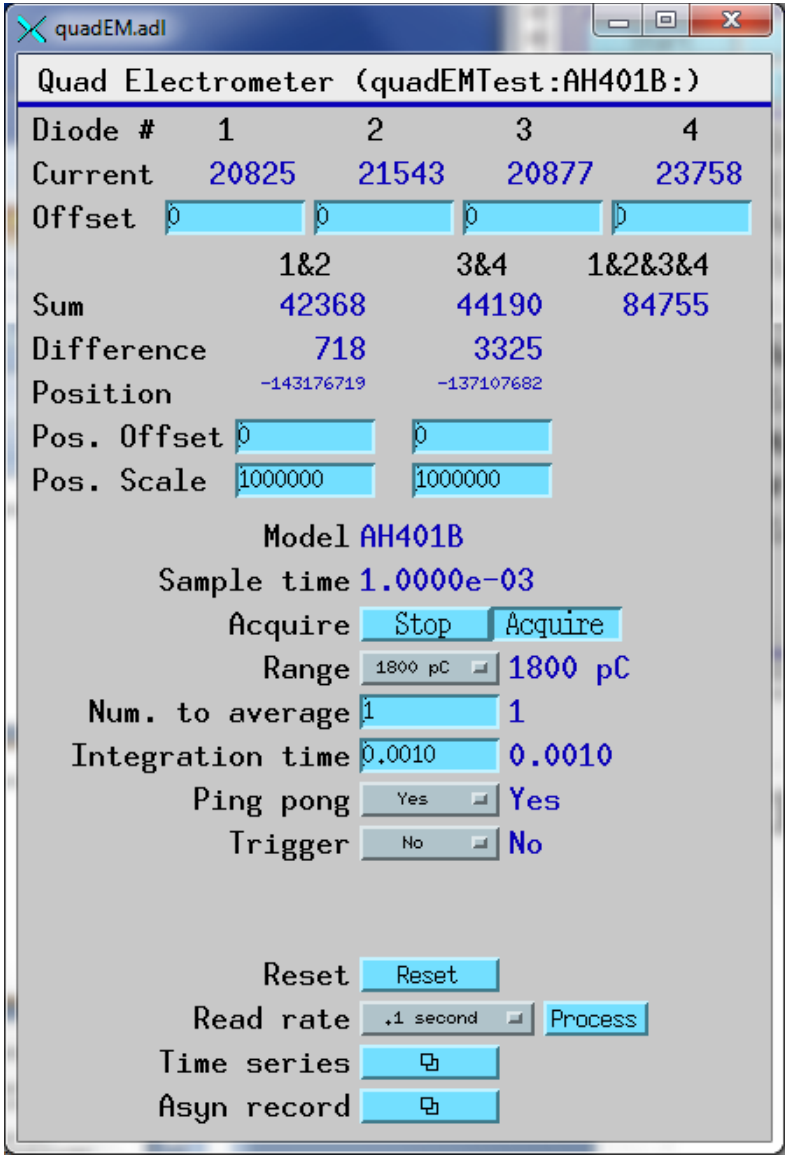


AH401 Series

- 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

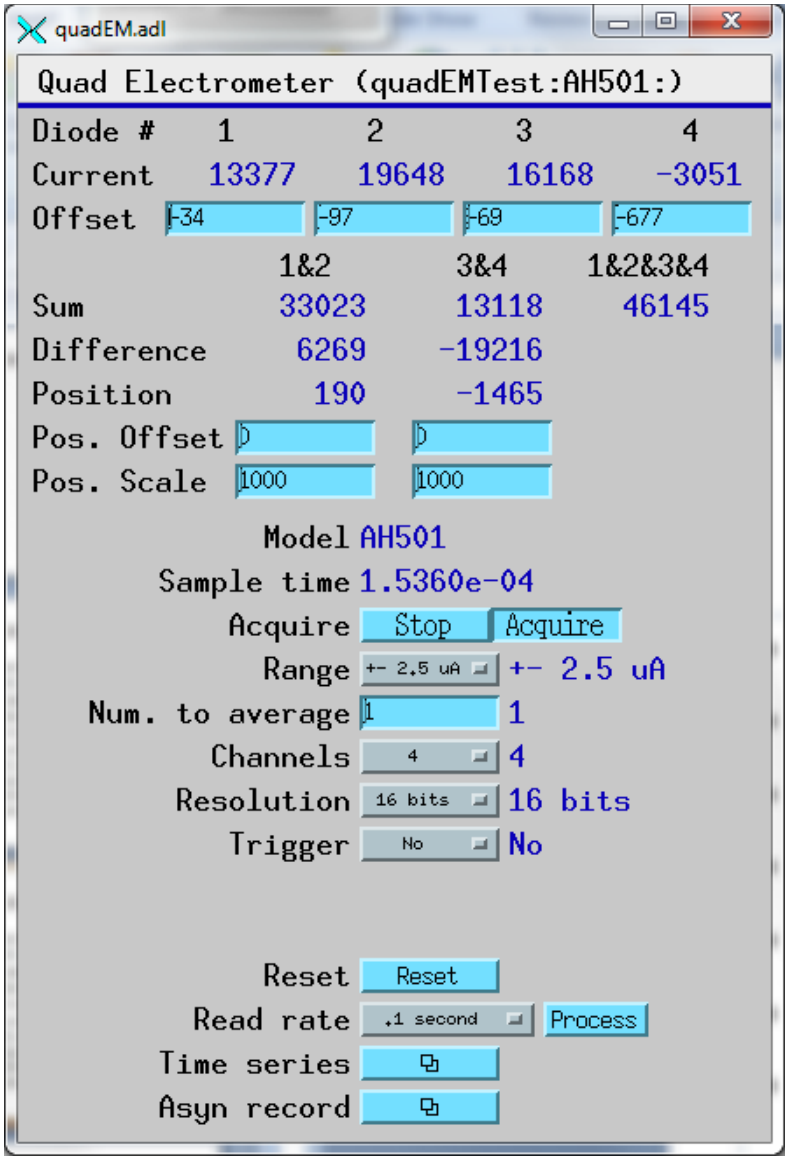


AH501 Series

- Based on transconductance amplifier
- 3 ranges: +- 2.5mA, +-2.5uA, +-2.5nA
- 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 µsec * 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



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)

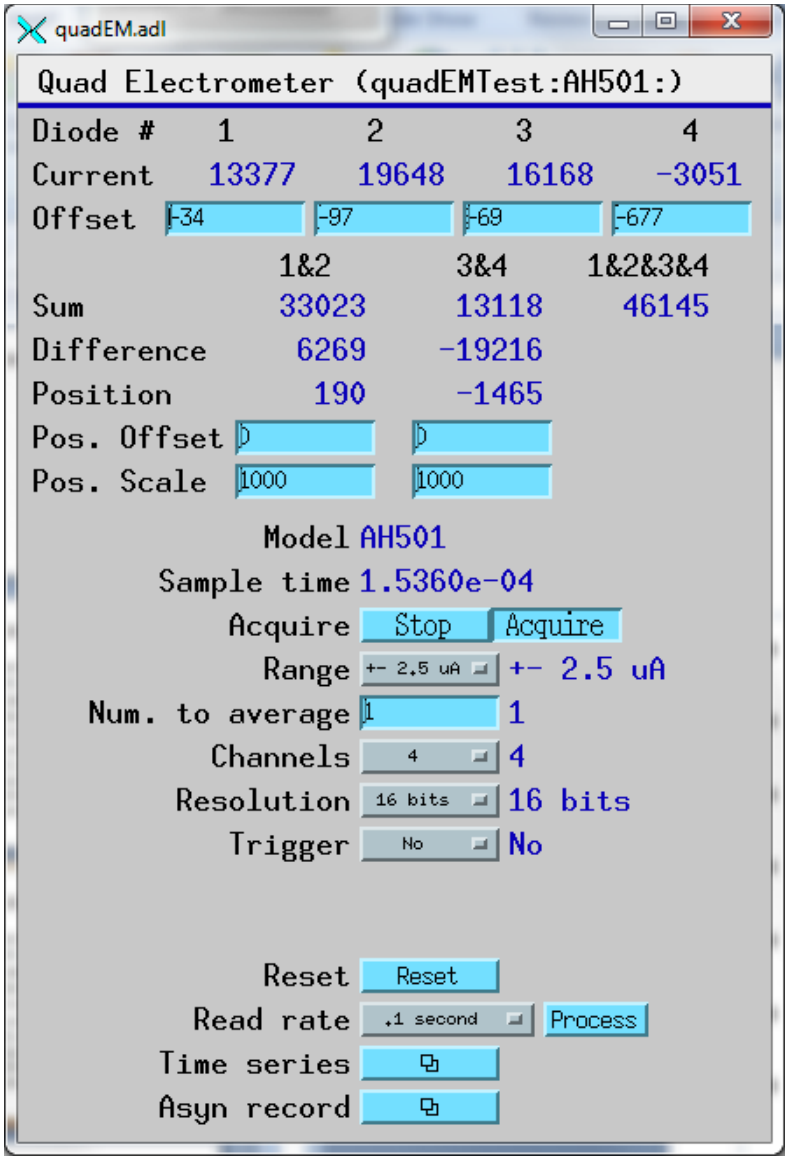
EPICS Software – Hardware Specific Controls

- 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.

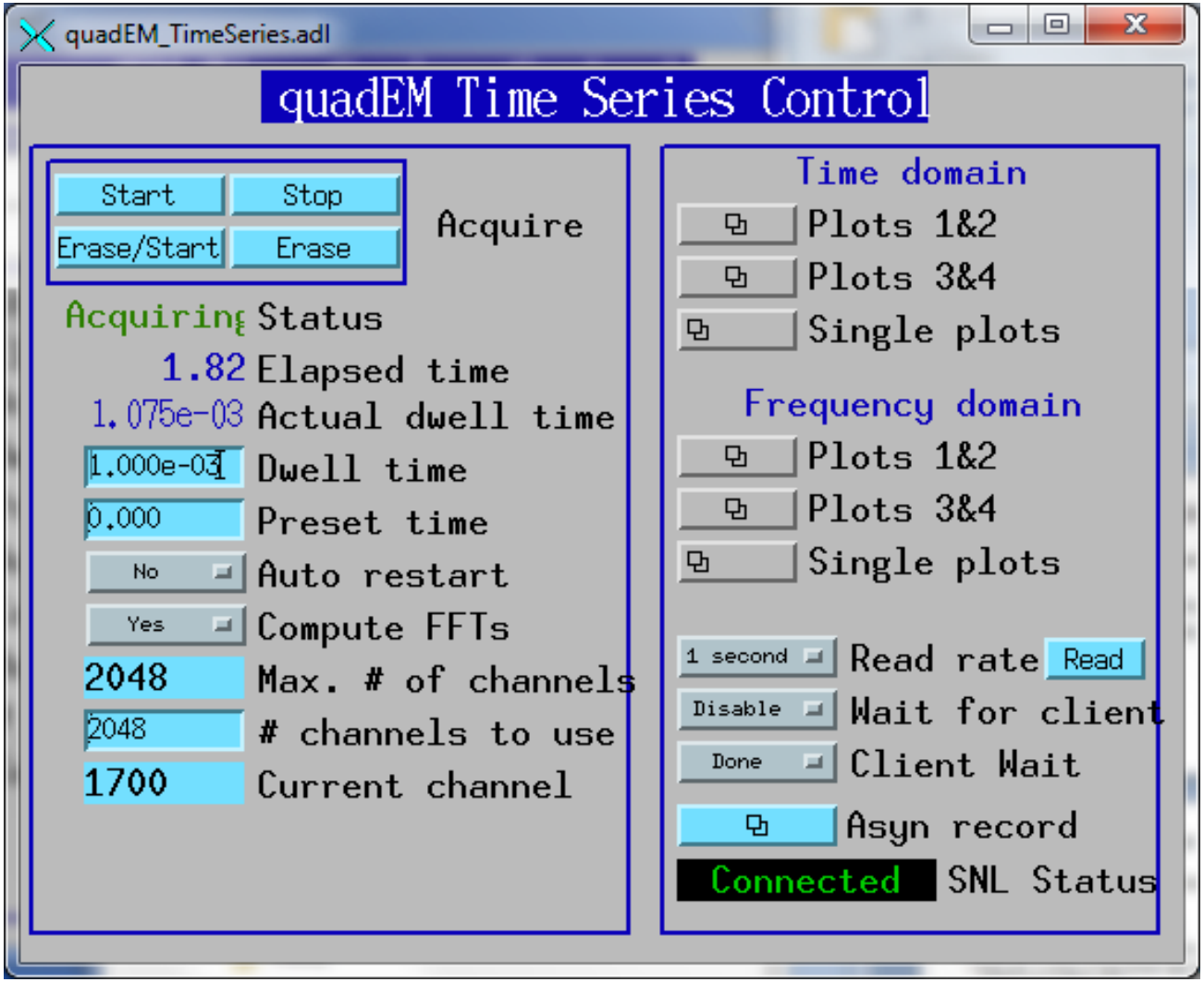
AH501 Series



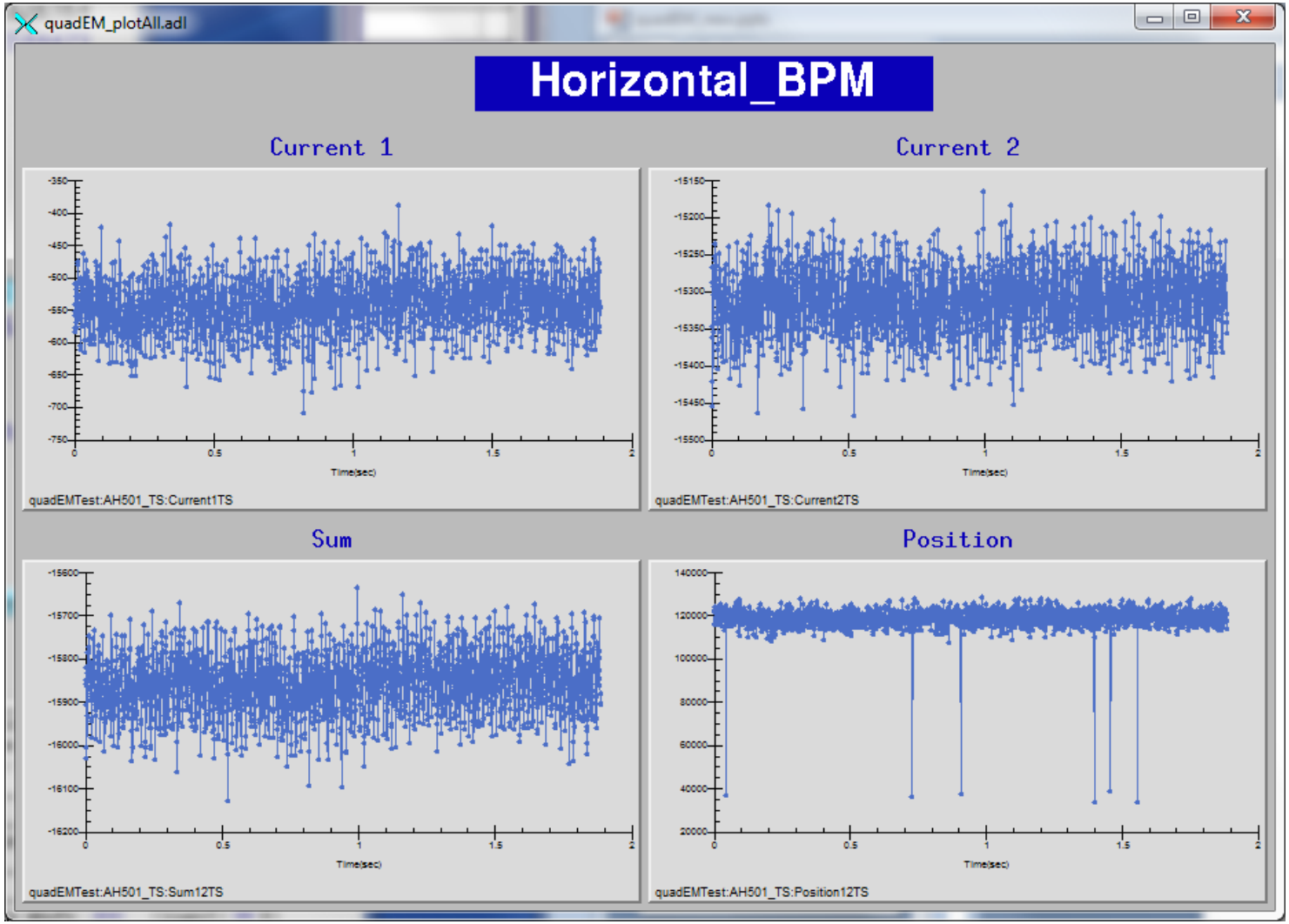
EPICS Software – Time Series

- 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)

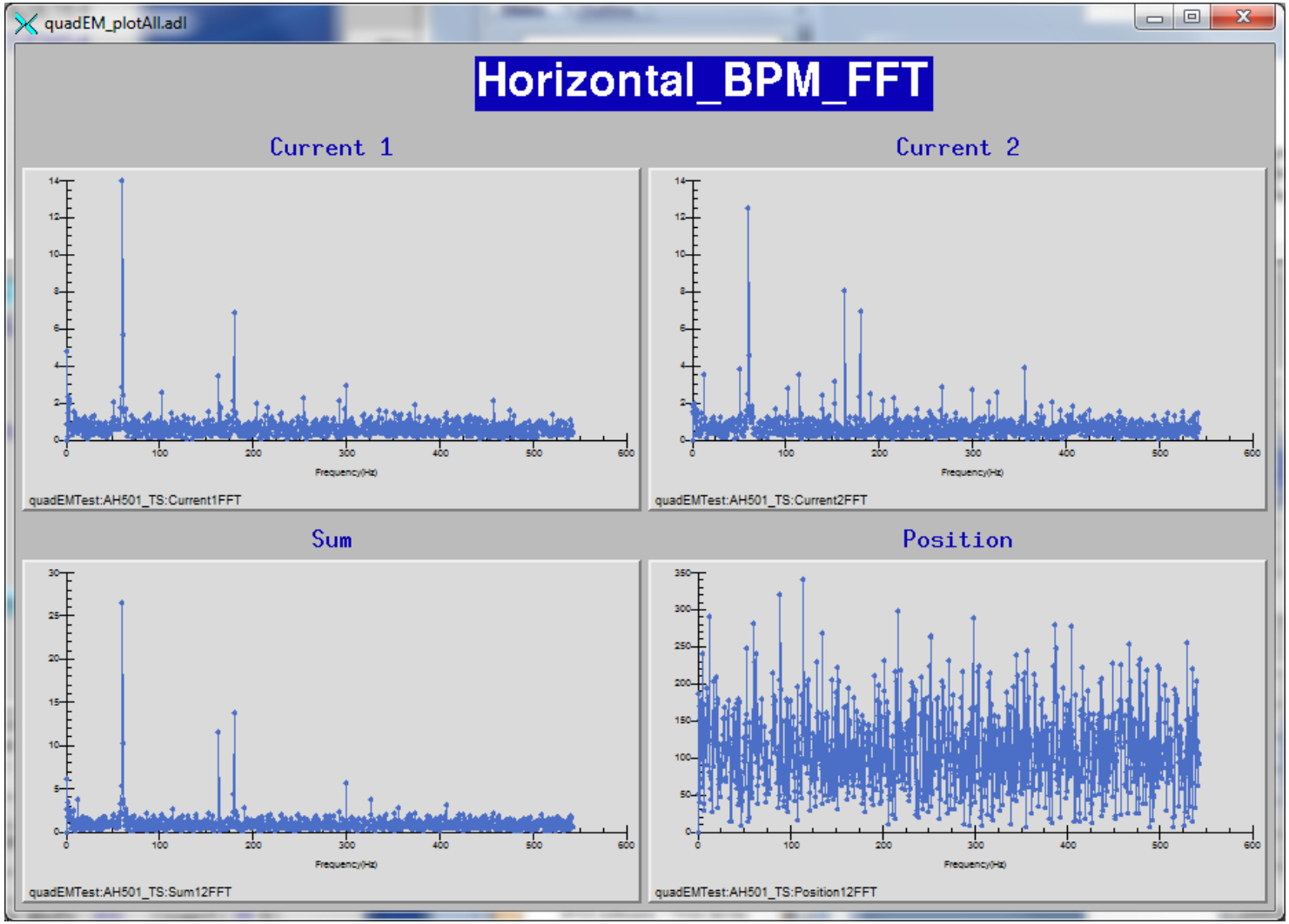
EPICS Software – Time Series



EPICS Software – Time Series

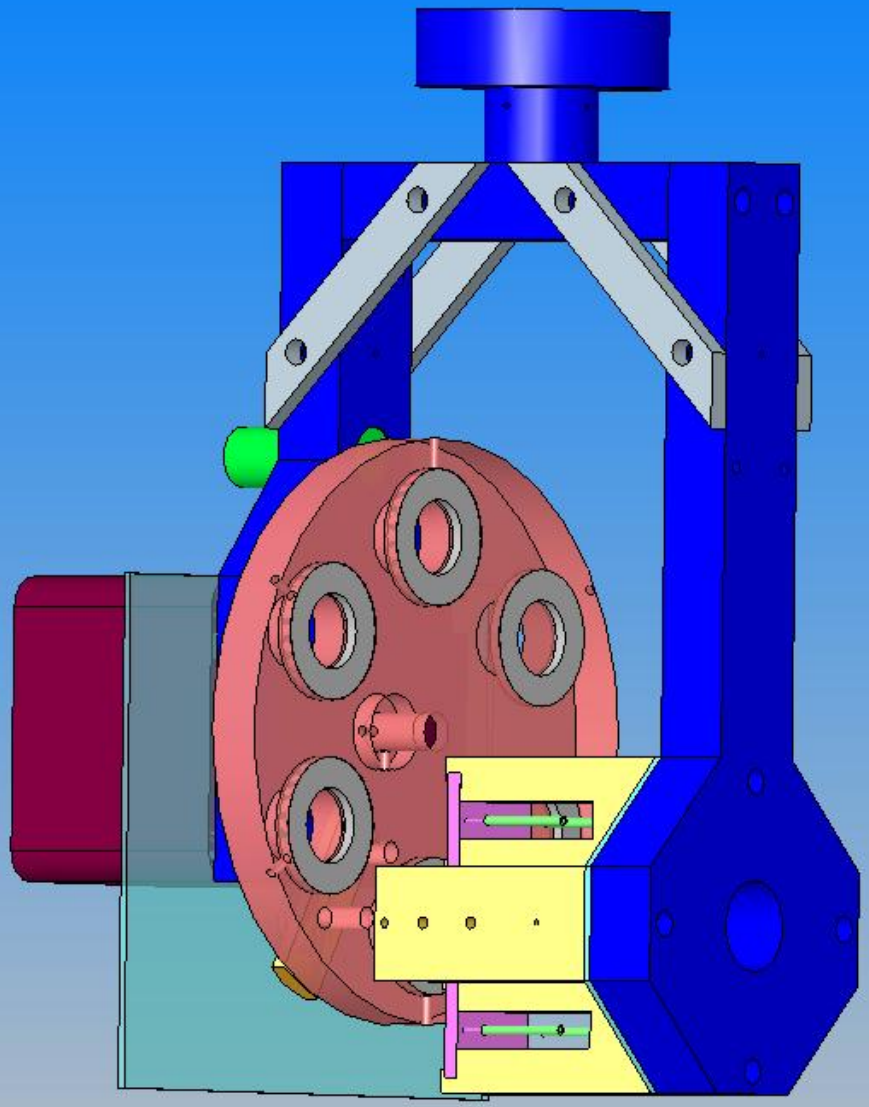


EPICS Software – FFT Power Spectra

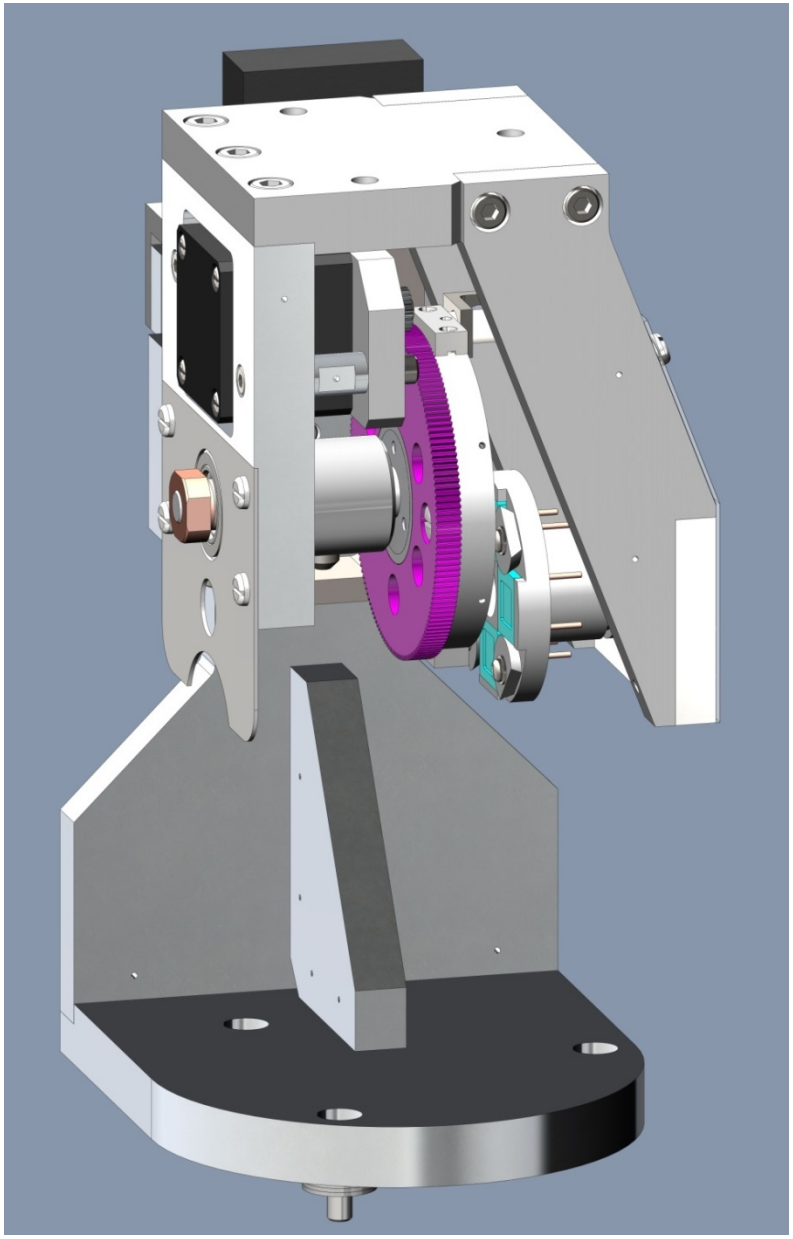


Demo

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

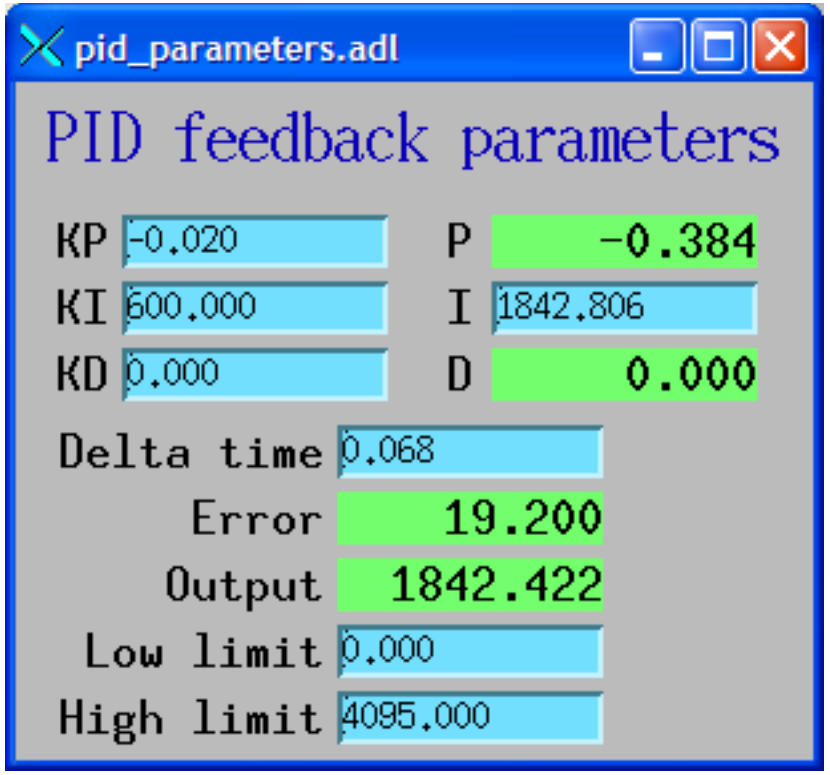
“Slow” Feedback

- 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

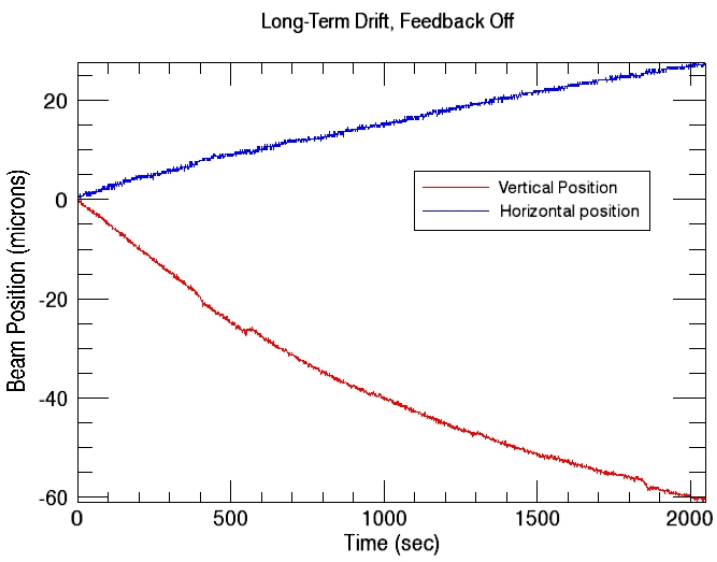
“Fast” Feedback

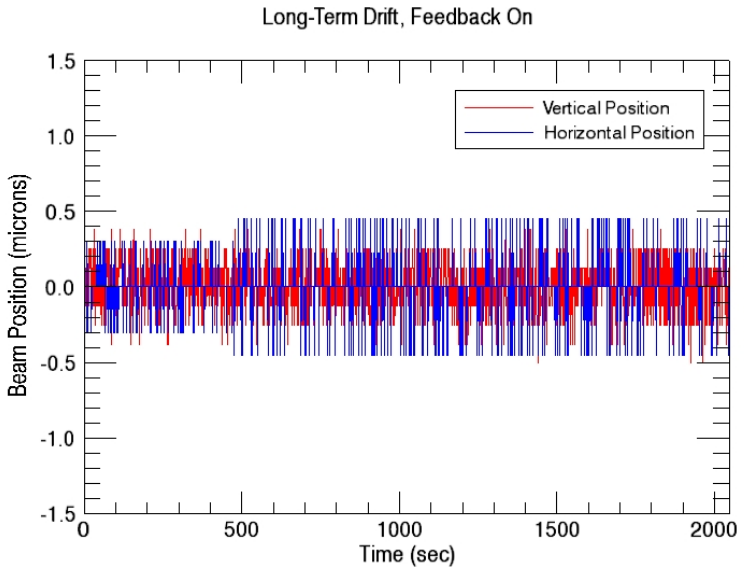
- Input from any asyn driver that supports asynFloat64 with callbacks (e.g. callback on interrupt), e.g. quadEM driver
- Output to any driver that supports asynFloat64.
- Very fast
  - Up to 10 kHz feedback rate
- Feedback rate is constrained to be an integer multiple N of device sampling time
  - If 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 periodially at 10Hz to provide snapshots of the feedback process

“Fast” Feedback

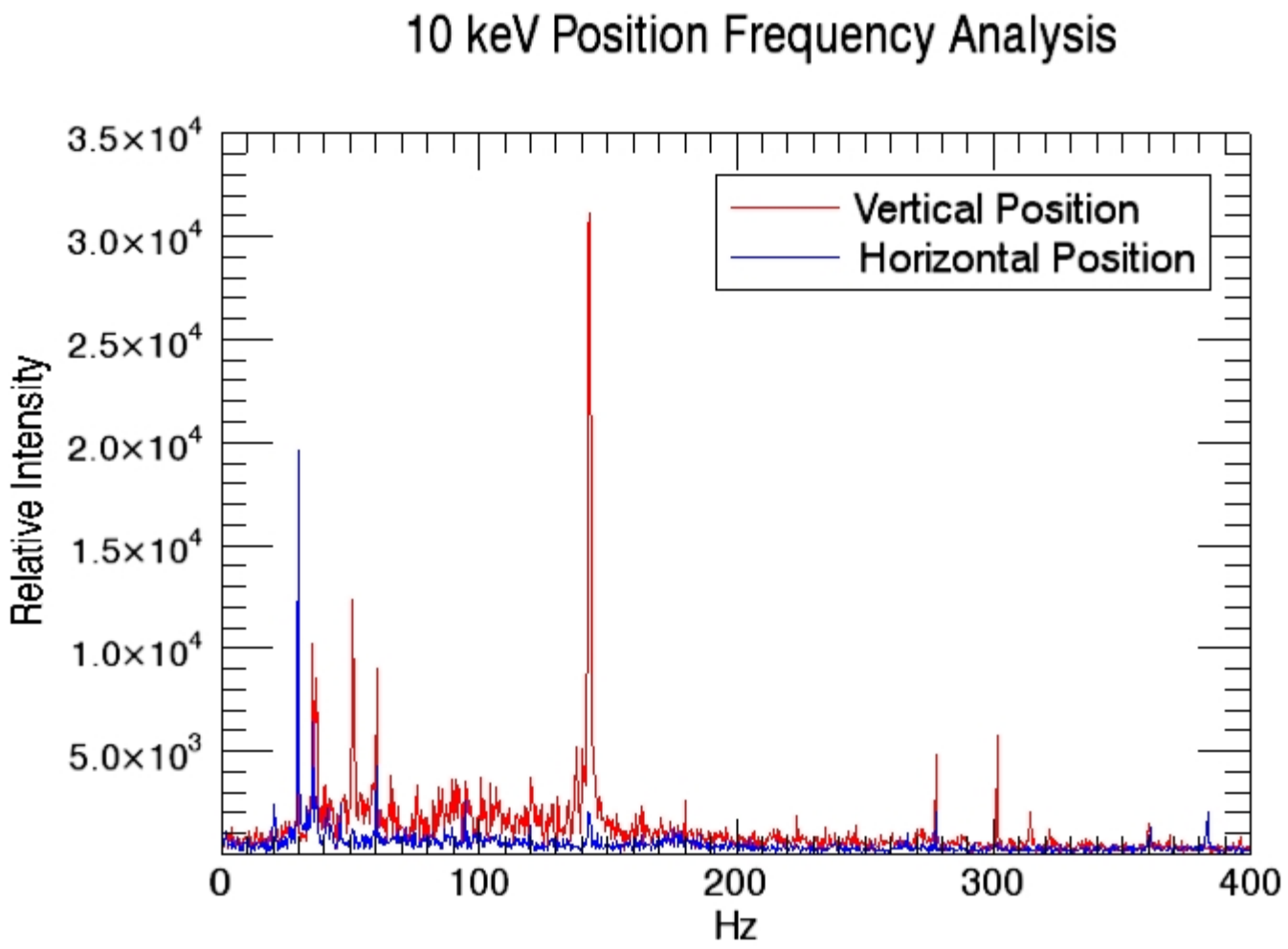


Example Application: Monochromator Second Crystal Stabilization





Example Application: Monochromator Position Frequency Spectrum



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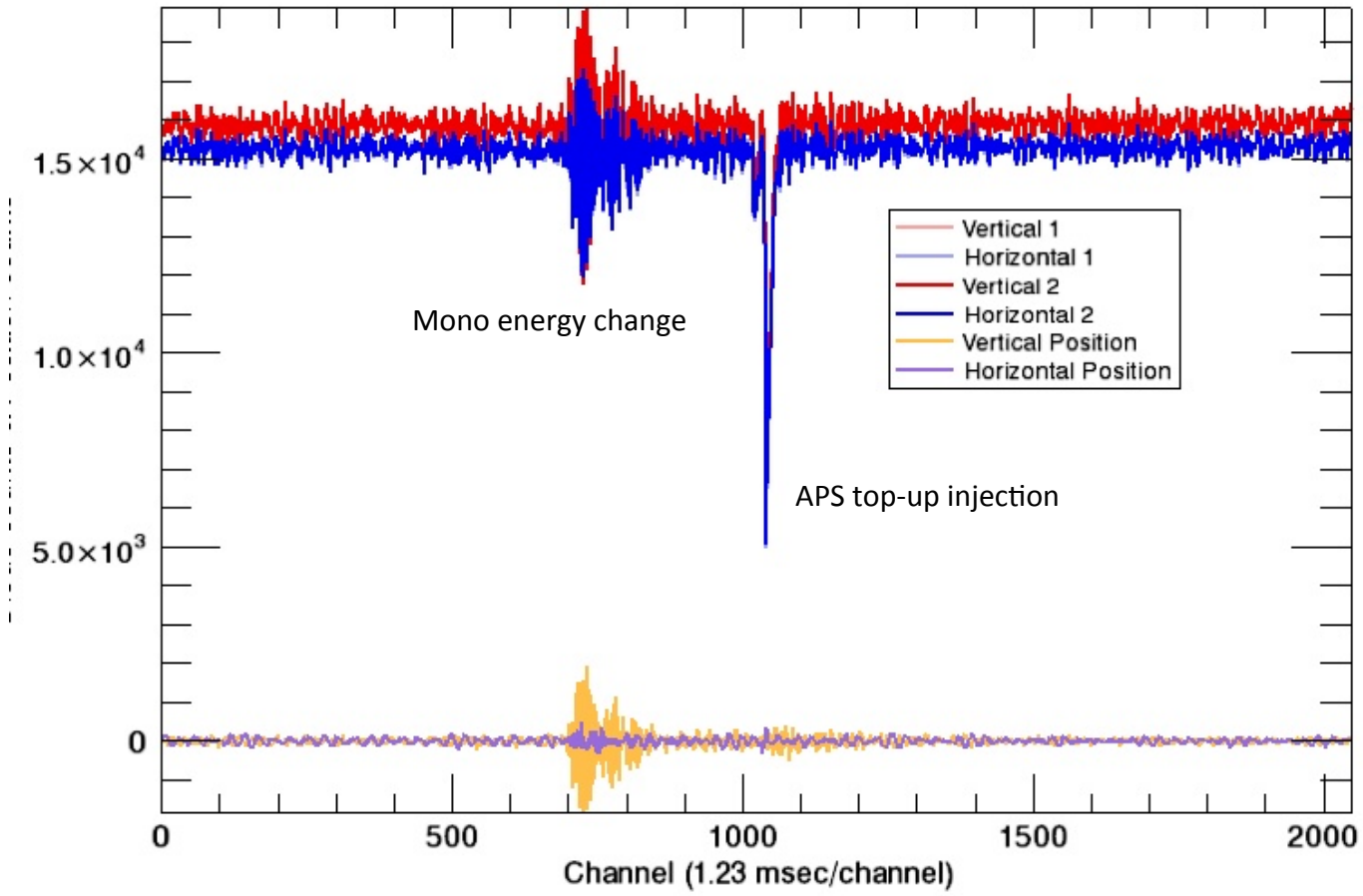

Conclusions

- 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!