Moving on from VME without Breaking the Bank

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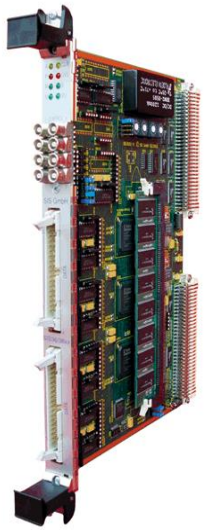
Motivation

- VME has a few advantages:
  - Has been quite reliable
  - Has predictable interrupt response time
  - We have a lot of $$$ invested in it
- VME has many disadvantages:
  - Very poor price/performance
  - Difficult development/debugging environment
  - Aging technology:
    - Existing devices becoming obsolete and unsupported
    - Few new devices being developed
  - Local vxWorks expertise is disappearing as staff retire

- We need to look to alternatives for the next decades of the APS
- Must not be too expensive because funds to replace a “working” system will be difficult to obtain

Current APS Beamline VME Functionality

- Analog to digital (IP330 and others)
- Digital to analog (DAC128V and others)
- Digital I/O (IP-Unidig and others)
- SoftGlue (IP-201)
- Counter/timer (Joerger VSC-16, SIS-3800, SIS-3802)
- Multi-channel scaler (SIS-3800, SIS-3802)
- Serial communications (IP-Octal and others)
- Motion control (OMS-58, MAXv)
- APS timing system (FRX-200, FRX-300, TMG-1)
- Allen-Bradley SLC-500 PLC communications (6008SV)

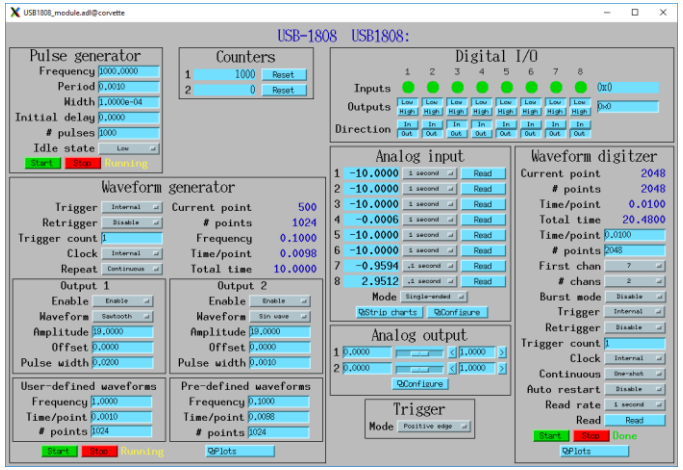


Will discuss affordable replacements for most of these.

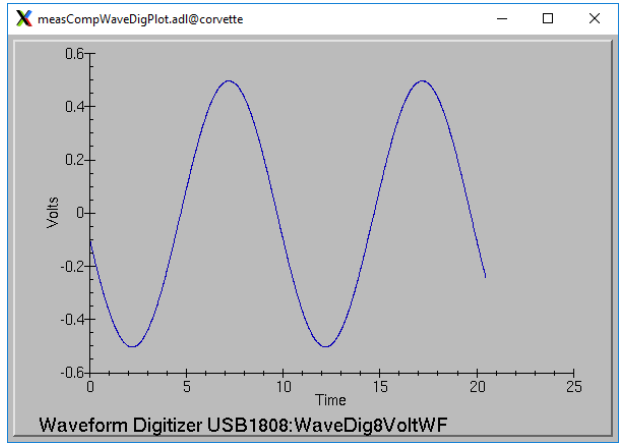
VME Replacements

- Serial control
  - Replace with Moxa terminal servers, very straightforward
- A/D, D/A, digital I/O, counter/timer/multichannel scaler
  - Replace with Measurement Computing Ethernet and USB devices
  - Uses the Measurement Computing libuldaq SDK on Linux.
    - Open source, vendor support
    - Supports all of their modules
    - Similar to, but not source compatible with their Window ULDaq SDK
    - EPICS drivers now make different calls for Linux and Windows

Measurement Computing USB-1808X ($979)



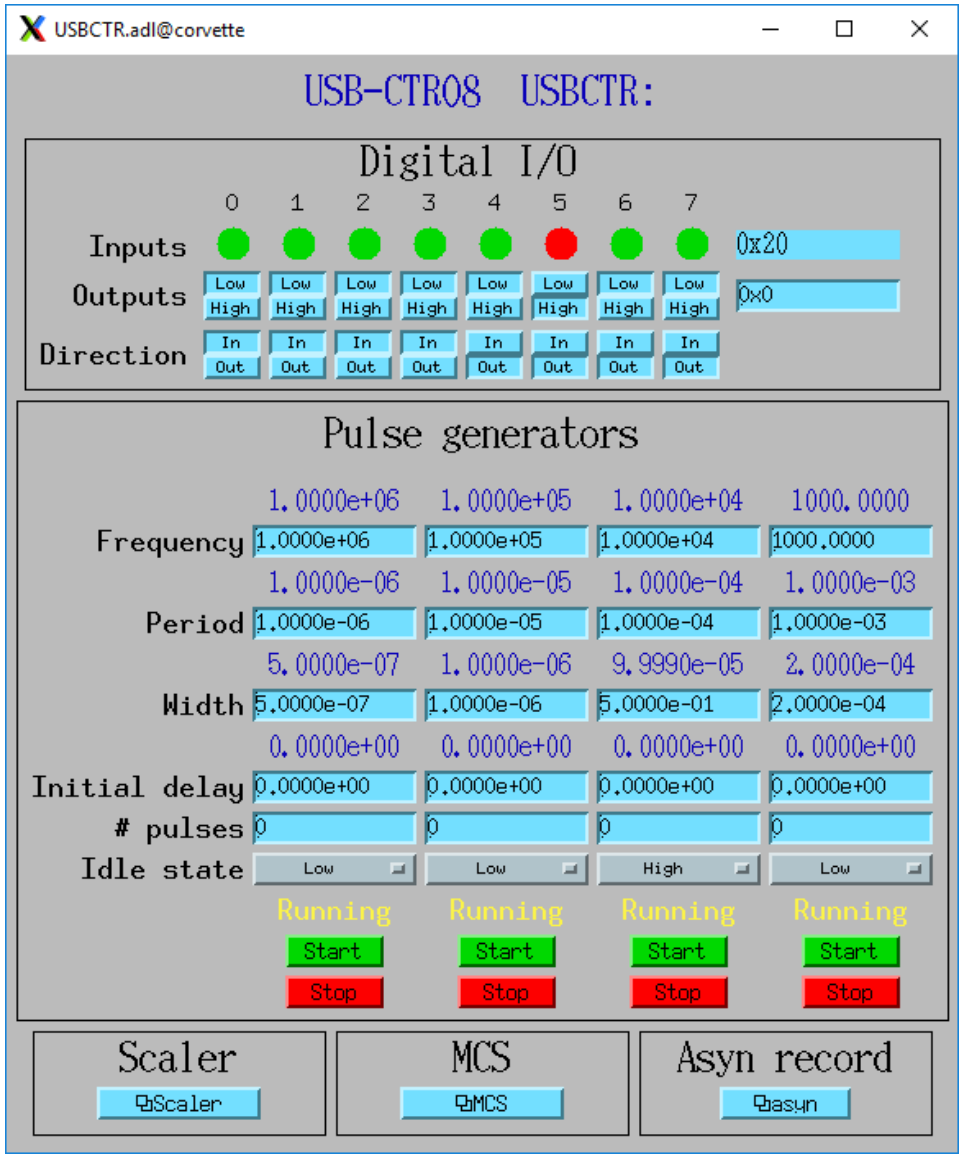
- 8 analog inputs, ±10V, ±5V, 0-10V, 0-5V ranges
  - Single-ended or differential
  - 18-bit, simultaneous sampling
- 2 analog outputs, 16-bit, +- 10V range
- 2 timing generator outputs, 50 MHz
  - Programmable frequency, duty cycle, polarity, number of pulses
- 2 differential encoder inputs, 50 MHz
- 2 counter inputs, 50 MHz
- 4 digital I/O, individually programmable direction
- Streaming input up to 200 kHz
  - Any combination of analog, encoder, counter, digital inputs
  - Up to 200 kHz
- Streaming output up to 500 kHz
  - Any combination of analog and digital outputs



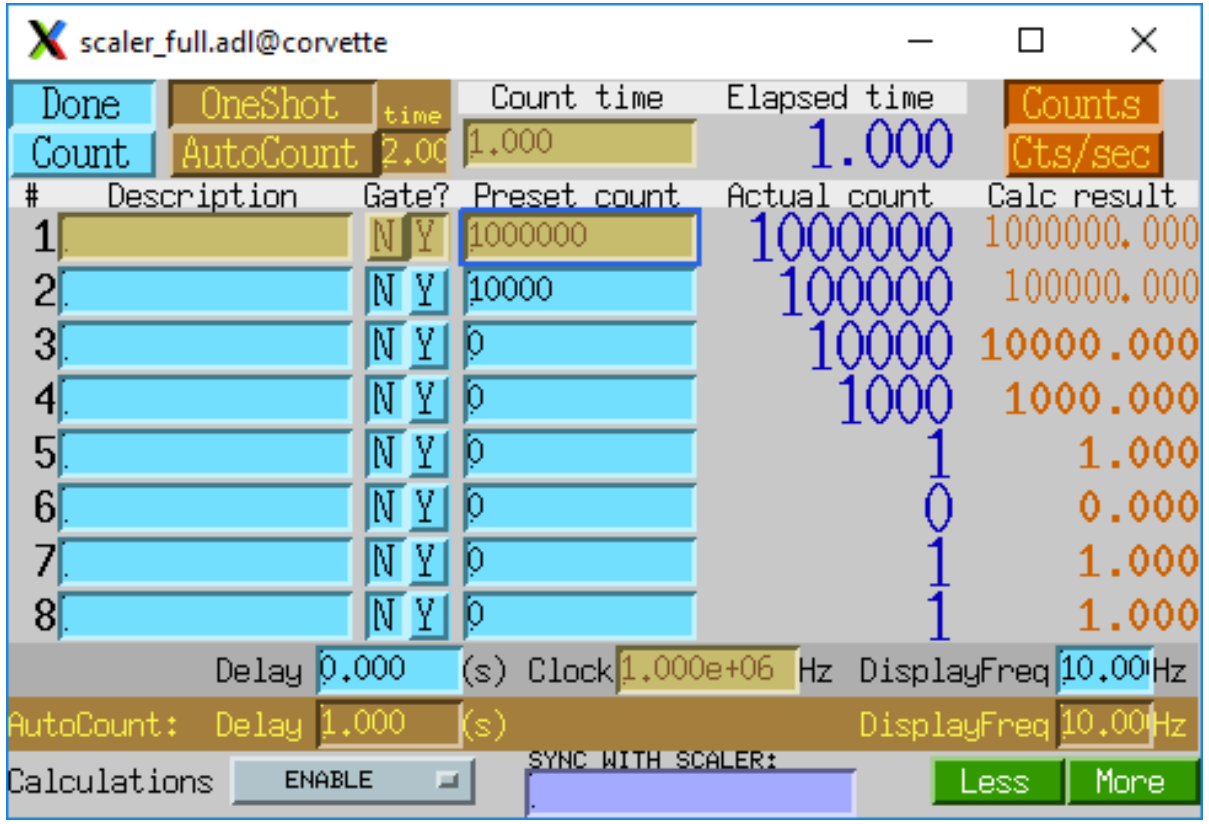
Measurement Computing USB-CTR08 ($489)
Replaces Joerger and SIS scalers and MCS

- 8 counter inputs, 48 MHz
  - 64-bit counter depth
- 4 timing generator outputs, 48 MHz
  - Programmable frequency, duty cycle, polarity, number of pulses
- 8 digital I/O, individually programmable direction
- Support for EPICS scaler record
- Support for Multi-Channel Scaler (similar to SIS 3820)
  - Minimum dwell time 250 ns per active counter
  - Can also capture value of 8 digital input bits in each dwell period

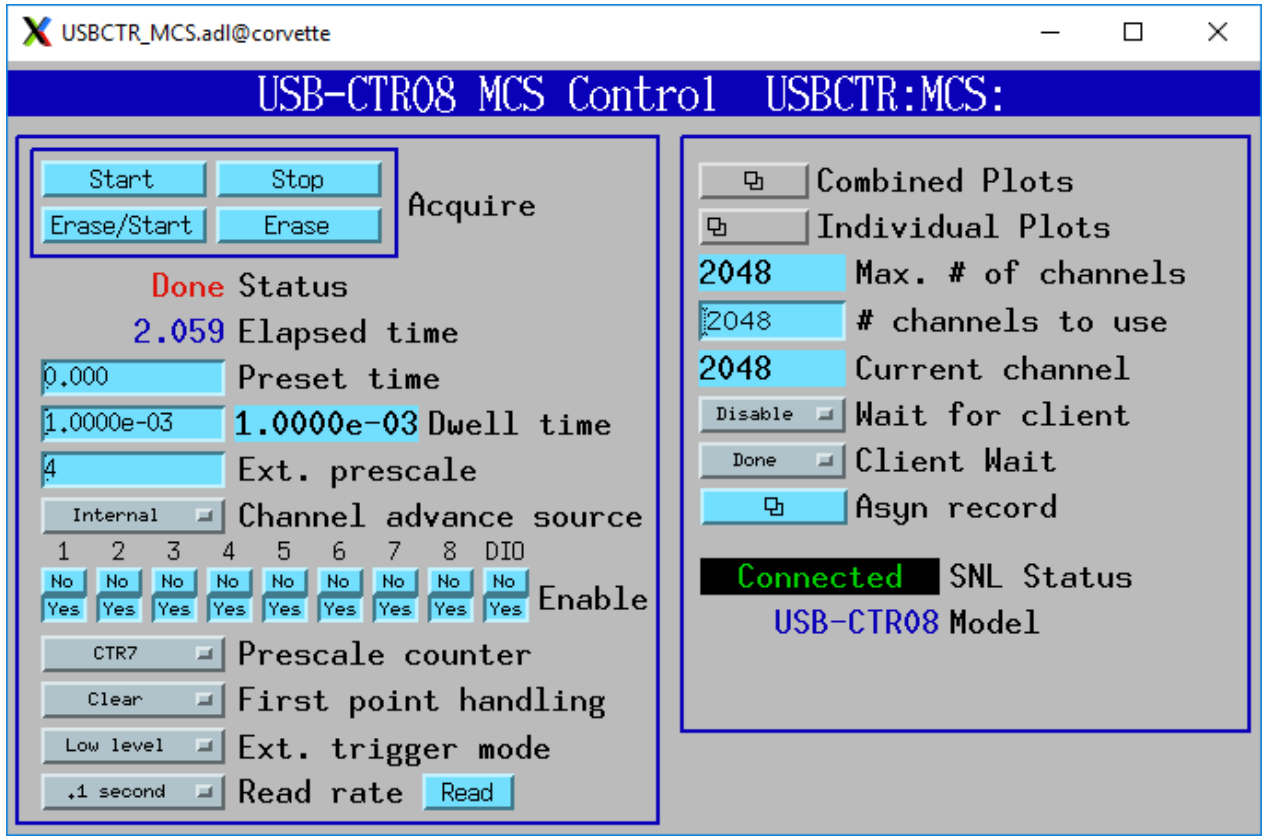
USB-CTR08 main screen

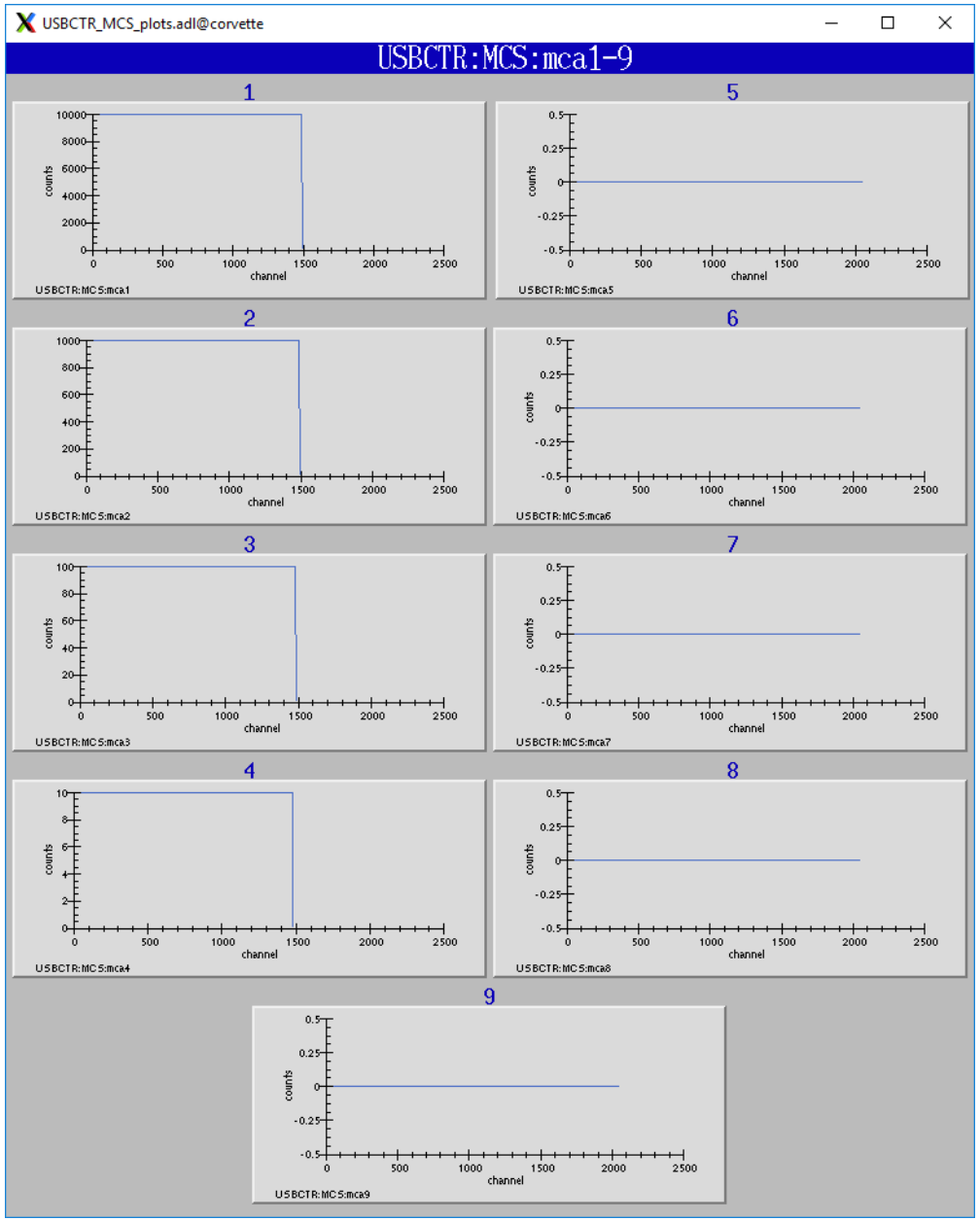


EPICS “scaler” record screen



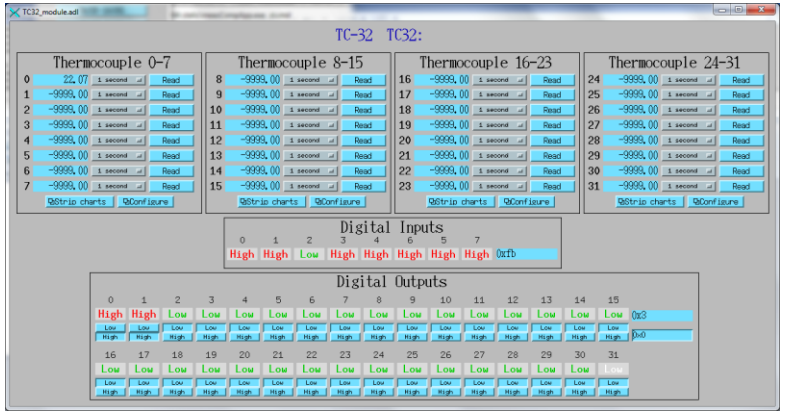
USB-CTR08 Multi-Channel Scaler (MCS) Mode





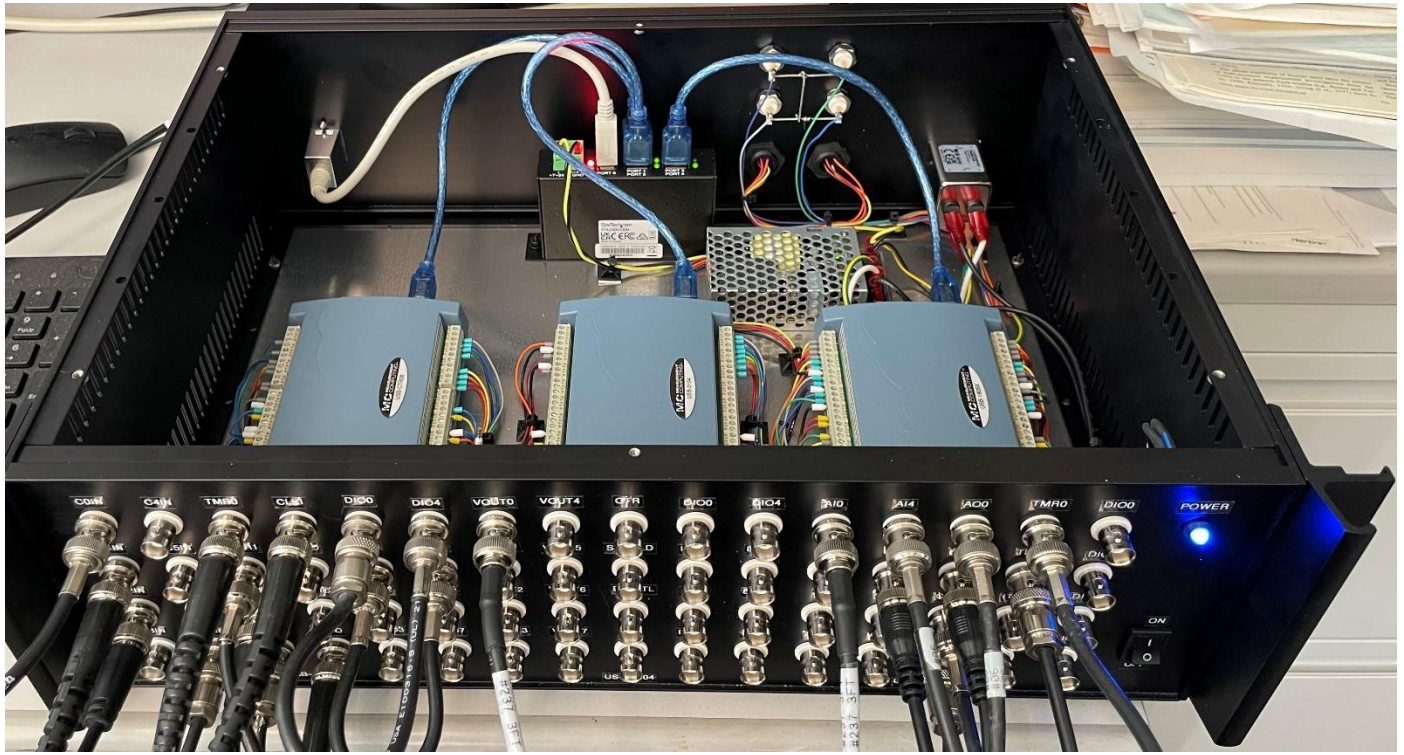
Temperature Measurement

- E-TC ($559)
  - 8 thermocouple inputs, 4 samples/s, types J, K, T, E, R, S, B, and N.
  - 24-bit analog outputs
- USB-TEMP ($629)
  - 8 temperature inputs, mix of platinum resistance thermometers (RTD), thermocouples, thermistors, or semiconductor sensors.
  - 2 samples/s
- E-TC ($2,319)
  - 32 thermocouple input, types J, K, T, E, R, S, B, and N.
  - 3 samples/s if reading all 32 channels, faster if reading fewer.
  - 32 digital outputs, switch-selectable pullup resistor
    - Each output can either be controlled by software or can be controlled by the alarm status of the corresponding thermocouple. Flexible alarm configuration, i.e. hysteresis.



Other Measurement Computing modules we will use

- E-DIO24 ($335)
  - Ethernet interface
  - 24 digital signals, individually programmable as inputs or outputs
- USB-310X ($459 - $689)
  - 16-bit analog outputs (4, 8, or 16)



Our enclosure for USB-1808X, USB-3104, USB-CTR08, 68 BNC connectors, 2 encoders

Motion Control

- This is the most challenging aspect of moving away from VME at reasonable cost.
- This is a count of the motor controllers and axes at GSECARS.

Motor controllers at GSECARS						
	VME		Non-VME			
	OMS-58	**OMS MAXv**	Newport XPS	ACS MCB-4B	Aerotech	Delta Tau
Total controllers	**44**	**8**	17	8	1	2
Total axes	**352**	**64**	136	32	7	14
Total axes	**605**					

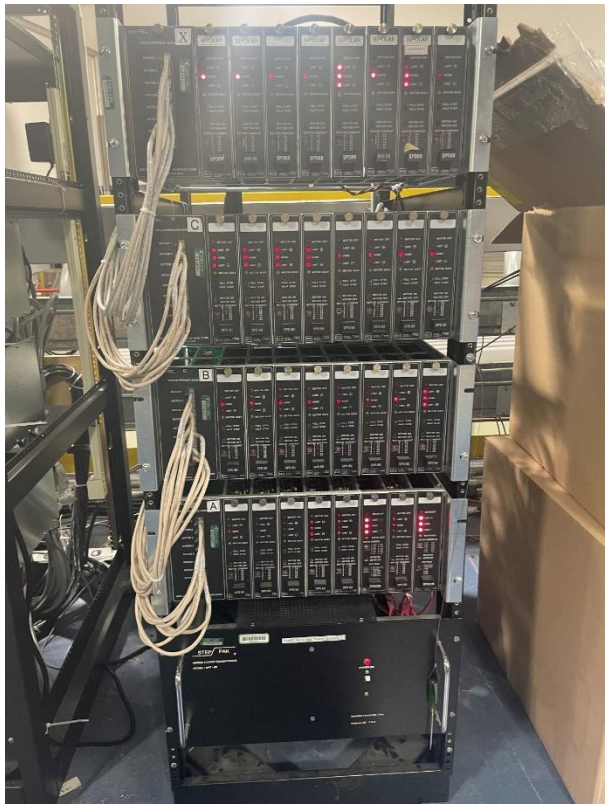
- Two popular non-VME motor controllers are Newport XPS and ACS MP4U. These each cost about $16,000 for an 8-axis version.
  - The controllers have advanced features like complex coordinated motion that are needed in some applications.
- GSECARS needs to replace 52 VME motor controllers, which would be $832K.
  - This is not feasible within our budgets.
- These are all controlling simple open-loop stepper motors, mainly with Step-Pak drivers.

Motion Control

- Much of the cost of the Newport XPS or ACS MP4U is the drivers.
- No need to replace the drivers, we can continue to use the Step-Paks or Phytron drivers that most beamlines are using.
- We mainly need an inexpensive Ethernet controller with pulse and direction output.

Phytron drivers

Step-Pak drivers



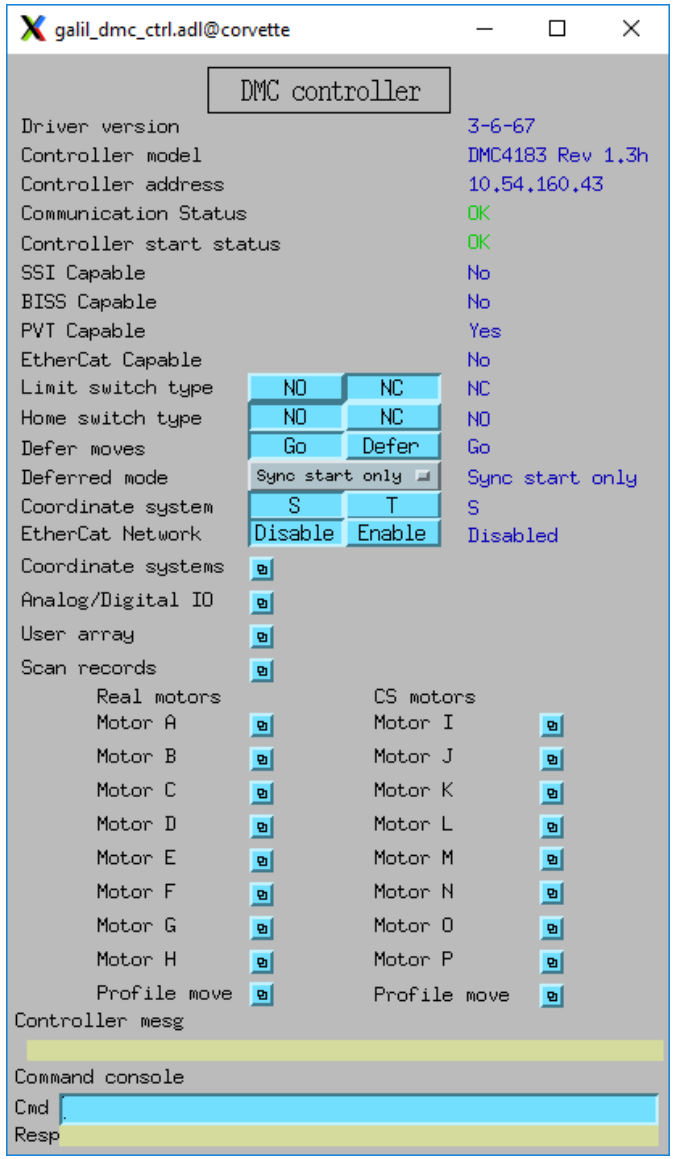
Galil DMC-41X3

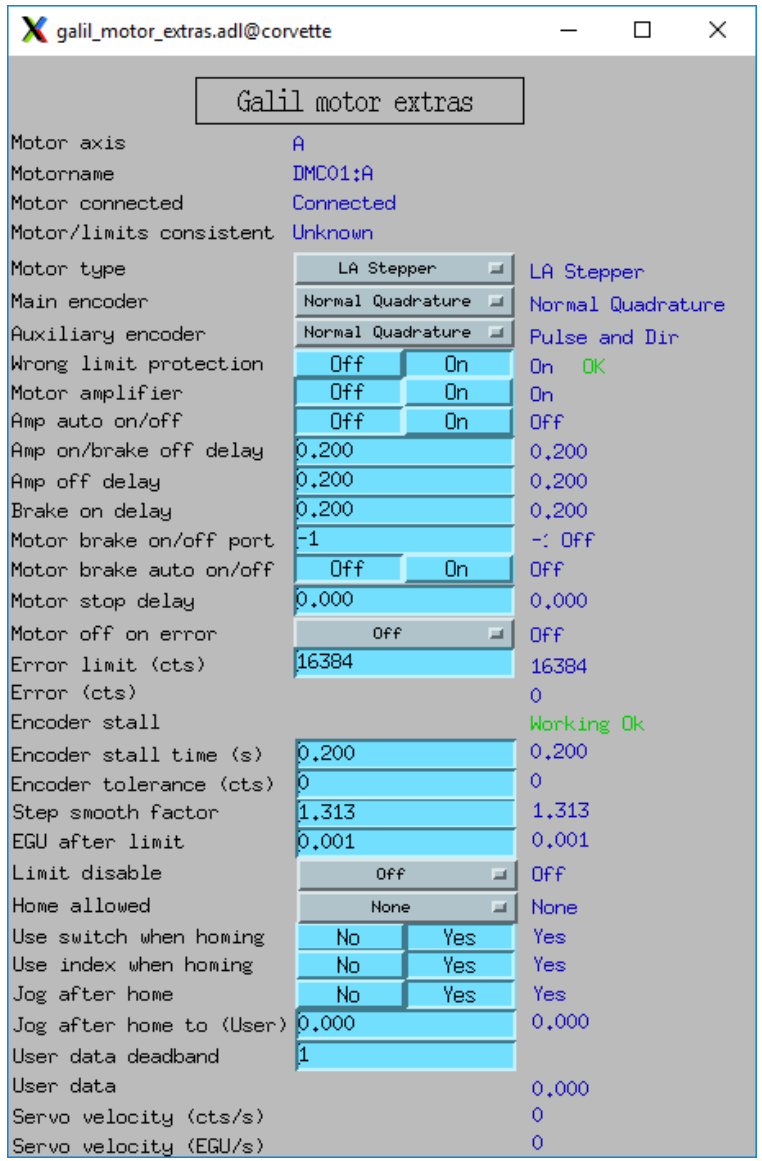
- Galil DMC-4183 (8-axis)
- DMC-4183 with enclosure costs $2,330 (quantity 1) and $1,620 (quantity 100)
- 6-9 times less expensive than XPS or ACS controllers.
- Ethernet interface
- Pulse and direction and analog drive outputs for steppers or servos.
- Optional on-board stepper and/or servo drivers.
- 8 analog inputs
- 16 optically isolated inputs and outputs

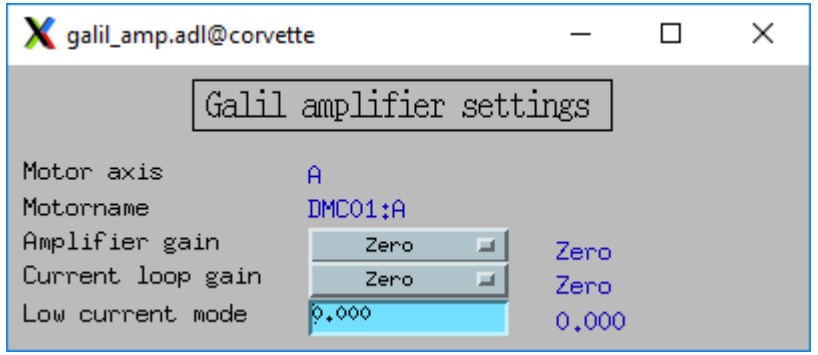
Galil DMC-4183

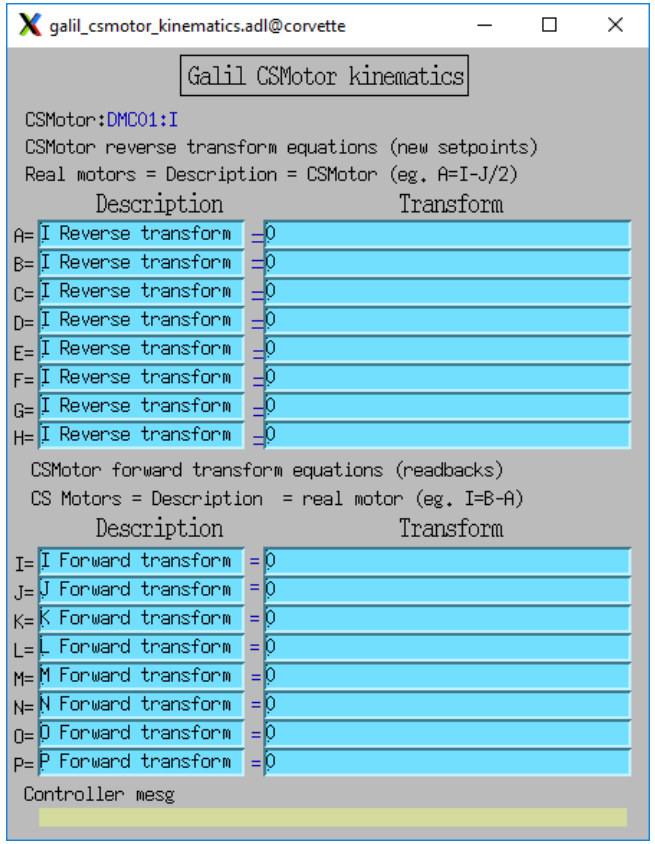
- Up to 15 MHz encoder frequency
- Multitasking for concurrent execution of up to eight programs.
- Optically isolated home and limit inputs.
- PID compensation with velocity and acceleration feedforward, integration limits, notch filter and low-pass filter.
- Modes of motion include point-to-point positioning, jogging, PVT, contouring, linear and circular interpolation, electronic gearing and ECAM.
- Mature EPICS driver written at the Australian Synchrotron
- Supports complex coordinated motion (EPICS profile moves)
- Supports Position Compare Output (PCO) for triggering detectors at specific positions
- Optional plugin amplifier boards up to 750 W.
  - 4 axis 1.4A microstepping driver plugin ($205)
  - 4 axis 3.0A microstepping driver plugin ($675)
  - Also servo and linear brushless motor driver plugins.

Galil Specific Screens – Rich Features



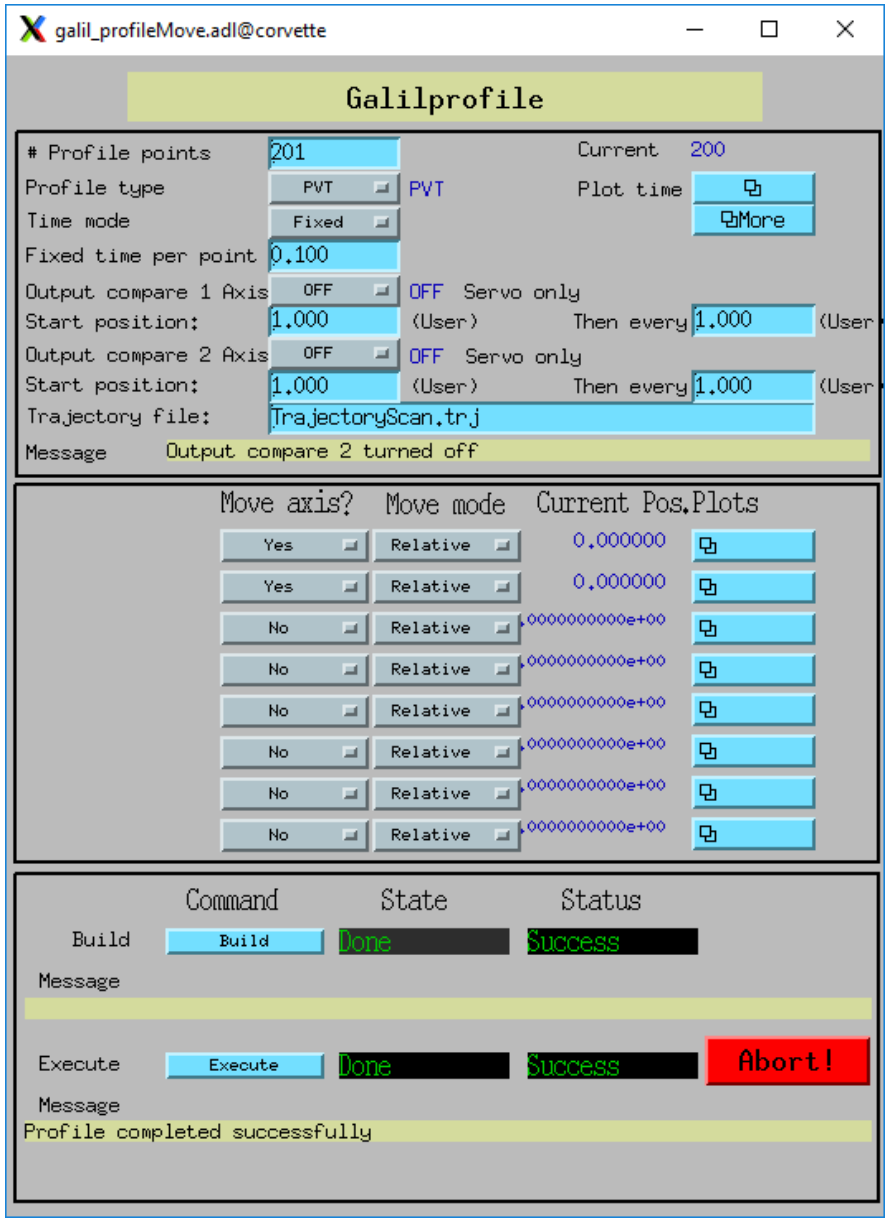






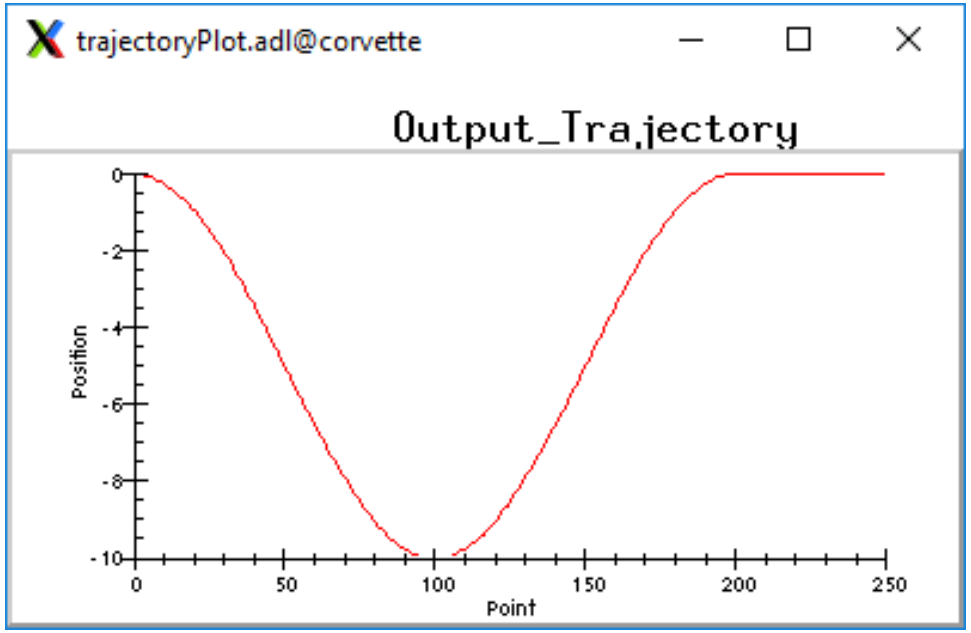
Multi-Axis Complex Coordinated Motion

- The EPICS driver for Galil controllers implements the Model 3 “Profile Move” interface.
- This supports complex coordinated motion
- PVs for the number of profile points and time per point.
- Waveform records define the position of each enabled axis for each point in the profile.
- Very similar interface to the Newport XPS profile move.

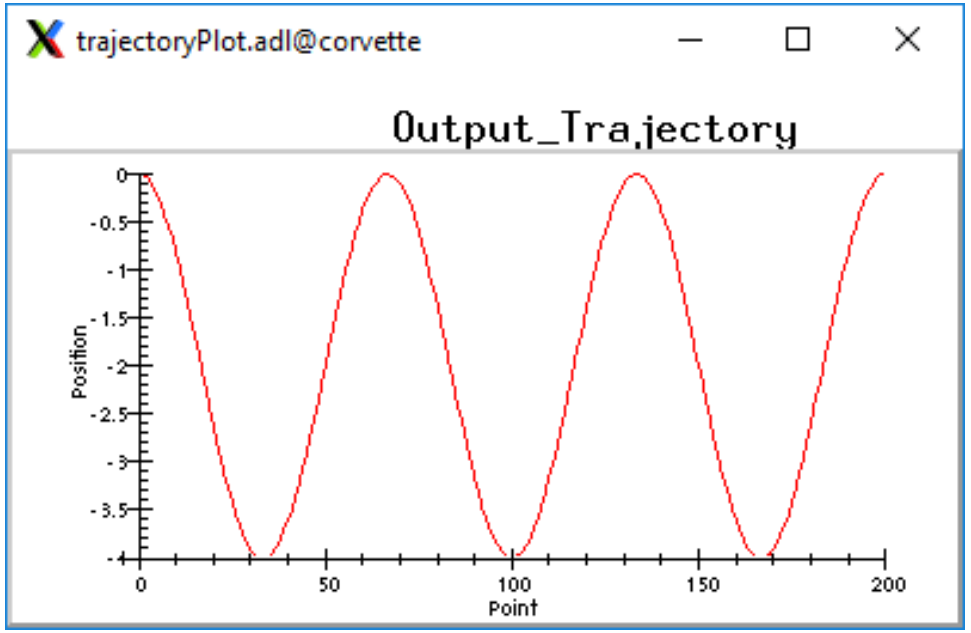


Multi-Axis Complex Coordinated Motion

```
>>> from galil_sin_profile_test import *
>>> galil_sin_profile_test(num_points=201, time_per_point=.1,
                           nperiods1=1, ampl1=5, nperiods2=3, ampl2=2)
Executing profile
```



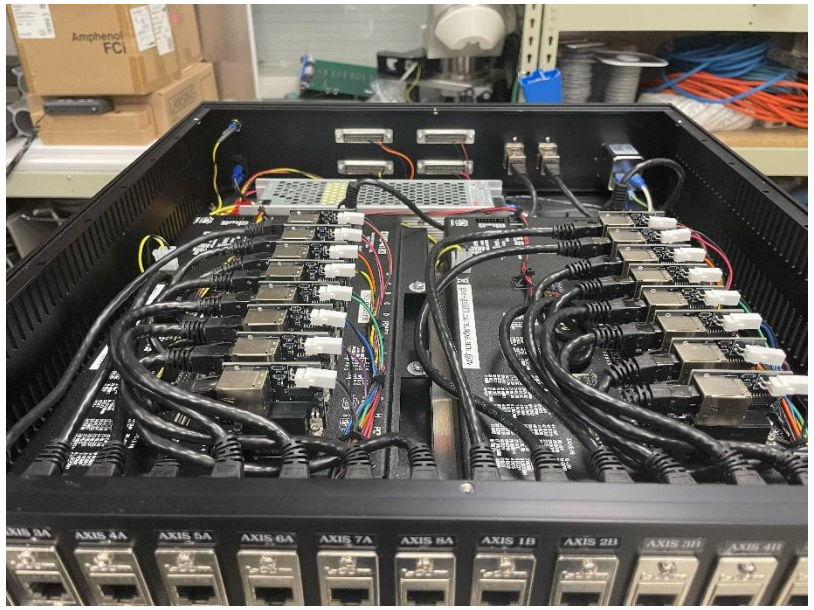
Motor 1 has 1 period with an amplitude of 5 rotations



Motor 2 has 3 periods with an amplitude of 2 rotations

Galil Packaging at our GSECARS Facility

1. 16-channel (2 DMC-4183, RJ-45 to Step-Pak, BNC step-out
2. 8-channel with 1.4A stepper drivers, ELCO connectors
3. 8-channel with 1.4A stepper drivers, ELCO connectors
4. 8-channel with 3.0 A stepper drivers, ELCO connectors



- 16-channel box with 2 Galil DMC-4183
- Custom circuit board for each channel
  - Differential line driver
  - HD-26 TO RJ-45 conversion
  - Step-out signal

- Step-Pak with RJ-45 cable connected from Galil to channel 1 of SPC-4 interface
- SPD-32M mini-stepper drivers

Status

- GSECARS plans to replace all 7 VME crates during current APS Dark Year
- Phase I is everything except motion control.
  - Have all required equipment
  - Estimate 2 months to complete
  - Will install 5 Galil systems, about 12% of final number
- Need about $100K to purchase remaining Galil controllers
  - Hope to begin Phase II motion control in September
  - Estimate 4 months to complete

THANKS FOR YOUR ATTENTION!!