Data Acquisition Equipment for NLCTA
Josef Frisch 12/22/00

NLCTA operations would benefit from a integrated data acquisition and control system. This document lists a possible configuration for such a system. It is desirable for the NLCTA control system to migrate towards a unified configuration as new equipment is installed.

Control system software: EPICS. EPICS is planned for use in the NLC. EPICS already provides much of the functionality required by the NLCTA. Additional NLCTA requirements are closely related to the NLC requirements, and would provide a useful test bed for EPICS development.

Form factor / bus: An attempt has been made to find hardware in VME 6U form factor. At the moment this is the only bus supported by EPICS at SLAC. VXI will be supported when an appropriate slot-0 controller is found. Even after VXI is supported in EPCIS there is a cost advantage to using VME where applicable.

PCI derivative busses (Compact PCI, PXI, etc.) provide higher performance than VME, but are not currently supported in EPICS.

There is considerable interest in using serial bus modules for NLC in order to improve reliability (due to reduced connectors), and reduce costs. It may be desirable to transition directly from a VME based system, to a serial based system, without an intermediate PCI step. A separate discussion of serial connected instruments should be initiated.

Control / diagnostics Hardware (Requirements / Options):

Interlocks - slow (120Hz): Includes Klystron interlocks. Can continue to use Allen-Bradley style control, to be integrated with EPICS. (This integration is already underway).

Recommendation: Present plan is good.

Analog IO - slow (<120Hz): Includes magnet power supply control, temperature monitoring, etc. Currently operated on the SLC control system. Can eventually be migrated to EPICS control using standard VME SMA / DAC modules.

Input: Bira 7305 VSAM, 32 channels, G=1-1000 front end, 16 bit.

Output: various available
VMIC VMIVME-4100 12bit x 16 channel (currently supported)
Acromag AVME9210 12 bit x 8 channel (currently supported)
VMIC VMEVME-4116 ($2600) is 16 bit x 16 channel. Software similar to 4100 (?)

Recommendation: Present plan is good.
**Acoustic Sensor Data:** The use of ultrasonic sensors for structure diagnostics is new for the NLCTA, and a new data acquisition system is required. Approximately 80 channels of 12 bit x 5MHz acquisition, with 4000 points / channel are required. This system will use multi-channel VME digitizers operating under EPICS.

Cabling of 80 channels from the sensors and pre-amplifiers in the tunnel to the VME crate may be a significant expense. A test of multi-conductor twisted/shielded cable should be performed.

A power spectrum of the acoustic sensor data (captured with a 8 bit, 12MHz digitizer) shows very little signal above ~2MHz. Digitization at 5Ms/s should be sufficient.

**HYTEC** VTR2535 8ch x 10MHz x 12 bit 128K samples/channel. $3890 ($486/channel). The inputs use 2-pin lemo connectors (a disadvantage). This unit is supported by EPICS. This unit is also available in a 14 bit unit, and 512K samples / channel. This represents the lowest cost and lowest software effort option. Delivery time is listed as 6-8 weeks.

**Joerger** VTR8128 ch x 10Ms/s, 128K samples / channel. $5495 ($687 / channel). This unit is also available in a 40MHz version (suitable for other NLCTA data acquisition). Other Joerger digitizers are supported by EPICS. This unit is available with very short lead time. This unit is relatively low hardware and software cost. Delivery time is 2-4 weeks.
The Interactive Circuits and Systems ICS-145-16 provides 16 channels of 5Ms/s (internally digitized and decimated at 20Ms/s to avoid aliasing), 16 bit A-D, 64K samples/channel. Unit is based on the AD9260 ADC. Cost is ~$10K. ($625/channel) This unit is (optionally) VME64 compatible. Note that there is also a 32channel 2.5Ms/s ($12,500), and 8 channel 10Ms/s ($8000). This unit uses oversampling to reduce aliasing. The oversampling introduces some complexities in triggering / clocking. This unit represents the best hardware performance.

*Pentek* 6109 8ch X 20ms/s 12 bit VME 16ks/ch ~$10,000 ($1250/channel). This unit appears to be too expensive.

*CAEN* unit V534 has been discontinued.

*Celerity* no longer plans to sell modules.

Recommendation: Bid the *Hytec* and *Joerger* units with a 6 week delivery deadline. Test multi-strand twisted pair cable.

**Integrated pulse diagnostics:** Torroids, integrated RF energy, PMTs, etc. These signals are currently read through the SLC control system, using CAMAC ADCs and TDCs. They should be transitions at to EPICS VME ADCs and TDCs. The need to correlate this data on a pulse by pulse basis with other signals (RF and acoustic) motivates a fairly rapid conversion to EPICS. (This conversion is underway, and some hardware is on order).

The *CAEN* V265 is supported by EPICS and meets our ADC requirements.

The *LeCroy* 1182 is similar in performance to the *CAEN* V265.

The *CAEN* V488 TDC is 12 bit, minimum 100ps range. (Epics supported?)

*LeCroy* 1176 TDC 16ch, 16 bit, 1ns TDC. (Epics Supported).

The *CAEN* V792 32 channel Q-ADC, and provides higher channel density, and multi-pulse storage. Should be considered for future use.

The *CAEN* V775 32 channel TDC, should be able to use the same driver as the V792, and should be considered for future use.

Recommendation: The NLCTA is already transitioning to EPICS / VME based pulse instrumentation. With low priority, higher channel density / performance modules should be evaluated.

**RF diagnostics:** There are a large number of RF test points in the NLCTA, operating at X-band with typical pulse lengths of 50 - 2000 nanoseconds. These signals can be monitored with a 20MHz bandwidth, 40Ms/s data acquisition system. The relatively low channel cost of this system should allow simultaneous monitoring of all RF signals.

The high cost of high speed digitizers motivates the use of a base-band down converter using an I/ Q mixer. This reduces the required digitization rate by at least 1/2. The disadvantage is the
requirement for calibrating the I/Q detector. In the following scheme this is achieved by switching in a calibration signal (4.4MHz offset from 11.424GHz) on every pulse.

A Xilinx based VME countdown and timing module will need to be constructed. Note that development of a similar module is planned for the NLC timing distribution system.

A RF module will need to be constructed.

Digitizer options:

The Joerger VTR812/40-128 8 channel, 40Ms/s, 12 bit, 128K record length unit is $7995 ($1000/channel). This unit is software compatible with the VTR1012 unit suggested for the acoustic system. Note that the input bandwidth is 120MHz. Delivery time is 2-4 weeks.

Hytec is developing the #2537 digitizer, but it is not yet available. Eventually will have specs similar to the Joerger unit, and will cost ~$4260.
**Echotek** ECDR-814/AD 65Ms/s, 14 bit. 8 channel. $12,000. Use of this board would allow higher measurement bandwidths. A digital receiver based on this unit is planned for use in the Spear-3 bpms.

**Echotek** FRADC-8-10242 is being discontinued ($13,00)

**SIS** has a 8 channel, 100Ms/s, 8 bit board under development. Expected delivery in March, for $4500. This is an attractive option if it is available in time.

Overall recommendations: Check on the development of the SIS unit. If not ready in time, use the **Joerger** unit. Have the NLC timing group concentrate on developing the VME countdown module and RF down converter.

**Fast RF diagnostics:** The RF signals have a bandwidth of ~200MHz. It is desirable to digitize these signals at >500Ms/sec. Either the I/Q down mixed signals (from the circuit above), or direct digital IF detection can be used.

The 40Ms/s data acquisition described above is probably adequate for normal signal monitoring. High frequency monitoring is probably only required for special testing, and arc location detection. RF switches can be used to send down mixed signals to the high speed digitizers when necessary. High average bandwidth is probably not required for the high speed digitizers.

There are currently problems with VXI controllers and high speed digitizers used at NLCTA. If these problems can be resolved, and the VXI control transferred to EPICS, The existing hardware is suitable. The NLCTA currently has 6 HP1428A digitizers (1Gs/S, 8 bit, 250MHz 2 channel). There are 2 reasonable options for operating theses under EPICS.

1. Use an EPICS compatible slot-0 VXI controller. It is not clear that any are available.

2. Use a VME - GPIB converter, and operate the units with the existing GPIB controllers. This is low speed, but probably adequate for this application.

If it proves impractical to operate the existing VXI equipment under EPICS, high speed data acquisition boards are available under VME. An EPICS driver would need to be written.

**Echotek** ECAD-1-081000 1Gs/s, 8 bit, 1 channel. $18,000, 12 weeks (very expensive!).

A possible alternative is to use a standard high speed digital scope with a GPIB interface controlled through VME through EPICS.

Recommendation: Use the existing VXI digitizers with either an EPICS slot-0 controller (if available), or with GPIB control through VME / EPICS.
Fast waveform generation: The NLCTA RF system requires high speed (~500Ms/s) arbitrary waveform generation for phase / amplitude control. Note that for near term tests, high data rate reprogramming of the arbitrary waveform generators is not required. It may be desirable to use a baseband I/Q scheme (similar to the decode scheme above) to reduce the required bandwidth of the generators. NLCTA has 6 Tektronix VX4792 arbitrary waveform generators (250Ms/s, 125MHz, 12 bit) in VXI format. If the VXI control can be converted to EPICS, these are suitable.

We have so far been unable to find any high speed VME arbitrary function generators. 100Ms/s units are listed below.

*Joerger VWG 100Ms/s 12 bit, 256Ksamples.*
*Echotek FRDA-4-14100 100Ms/s 14 bit, 2 channel*

Recommendation: If possible, use the existing arbitrary function generators in VXI under EPICS. Otherwise, need to look for a VME or GPIB instrument solution.

Special data acquisition: Video digitizers, GPIB, RGA control, etc. Video, GPIB and serial ports are available on VME bus. Special devices like RGAs, will probably require an interface through serial or GPIB to a stand alone (or PC based) instrument. Note that the desire to synchronize video data with other data acquisition (for arc detection for example) motivates the use of a directly EPICS controlled VME frame grabber board.

Video Frame Grabber: *Dynatem DFG1/2* (Generic low cost frame grabber). VxWorks driver available.

GPIB interface: *National GPIB-1014 $1295*, EPICS supported.

Serial interface: *VMIC VMIVME-6016*, various others available.

Recommendation: Continue to develop EPICS ability to support miscellaneous devices. Choose a VME video digitizer for EPICS.

Future requirements: For a variety of projects (BPMs, LLRF, etc.) there is a need for a high speed, high accuracy digitizer board. 714Ms/s is probably a good design point to match the maximum bunch rate. SLAC could develop 2 modules:

The first uses a commercial Gs/s digitizer (e.g. *Maxim MAX104*) with a high speed FIFO, and logic (Xilinx?) to transfer the data to dual ported memory. Note that if 714MHz FIFOs are not available, high speed de-serializers can be used with slower memory. The design should be compatible with high speed 12 bit units if/when they become available.

The second is an interface from VME to the dual port memory. This interface is available in a (nearly) one chip solution from Cypress semiconductor.
Later, when we transition to a high speed serial interface, the second card can be replaced with a serial to dual port memory interface.

Overall Recommendations:

1. Purchase ~80 channels of 10Ms/s, 12 bit VME digitizers (10 modules). Bid the Hytec and Joerger units.

2. Evaluate the number of 40Ms/s digitizers required for RF diagnostics. Evaluate the availability of the SIS unit. If not ready in time, purchase the Joerger units.

3. Develop a baseband I/Q demodulator board for X-band (Timing group).

4. Develop a 357MHz based timing / phase distribution system (Timing group).

5. Either find a EPICS compatible VXI slot zero controller, or develop software to allow VXI control through GPIB through VME. This allows use of the existing (expensive) VXI digitizers and arbitrary waveform generators.

6. Try to transition Video frame grabbers, and other miscellaneous hardware to EPICS control under VME.

7. (medium term). Develop a 714 Ms/s 8 bit digitizer, initially in VME, designed for easy transition to serial link.

8. (long term). Select / develop a high speed serial interface standard for data acquisition.