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Upgrade of the NSTX Plasma Control System

D. Mueller, D. Gates, M. Isaacs, J. Lawson, R. Marsala, D. Mastrovito and P. Sichta
PPPL, Princeton, NJ 08543 USA

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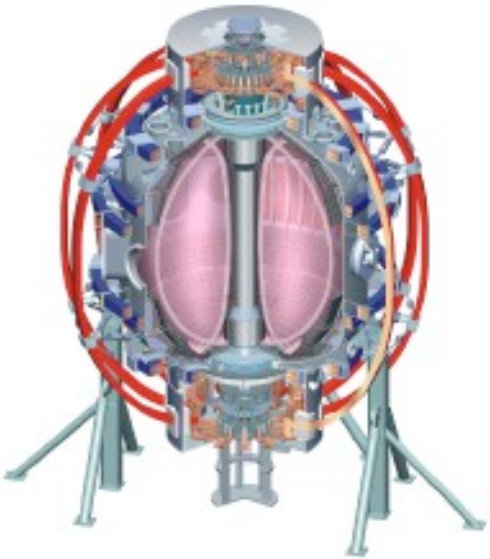

Abstract

The plasma control system for the National Spherical Torus Experiment (NSTX) has been upgraded to replace the obsolete SKY computer system. The three main improvements with the new system are 1) higher computer speed, 2) lower latency and 3) a recordable absolute time during the discharge. The eight 333 MHz G4 processors in the Sky system were replaced with four dual core AMD Opteron 880 2.4 GHz processors. This provides approximately 7 times the speed for computationally intensive parts of the control system. The data acquisition and control were previously shared between VME and front panel dataport (FPDP) hardware. Two PCI FPDP cards, one each for data input and output made elimination of the VME hardware possible. Presently, the input data is read directly from the FIFO, this results in a loss of speed compared to the full potential of the vmetro FPDP DPIO2 boards using DMA, nevertheless, the present latency is about 2/3 that of the old system. In the old system, time was computed relative to a start trigger and was calculated based on input data frequency and the real-time cpu clock frequency. A digital input and time stamp module (DITS) was developed to provide a 48 bit absolute timestamp for each input data sample.
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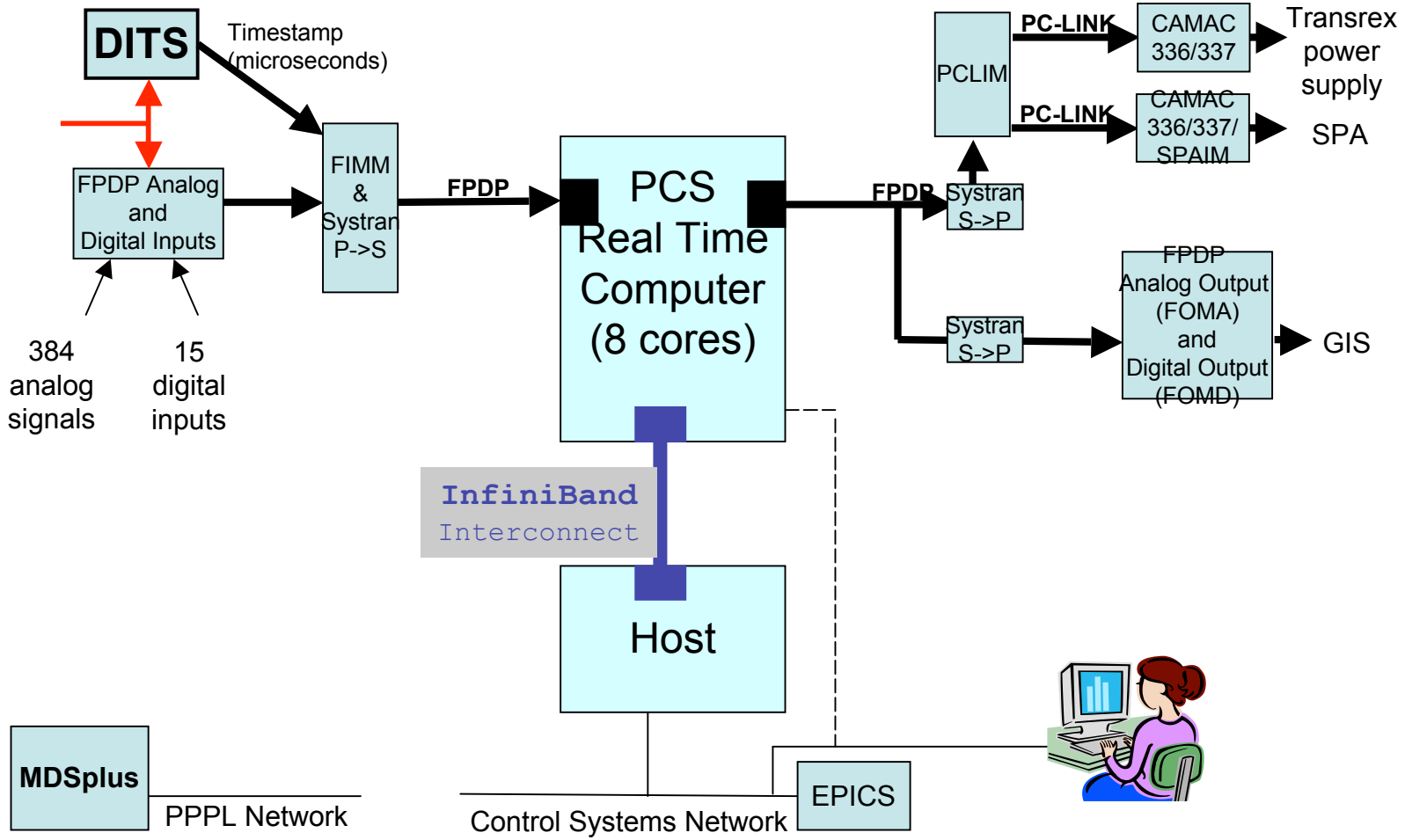
Goals of upgrade

- Replace obsolete SKY computer system
- Replace VME used for gas injection control with FPDP protocol
- Increase CPU speed ~ 8X for calculation intensive functions (rt-EFIT)
- Decrease system latency
- Provide hardware time stamp for data
- Add archival and restoration functions for engineering power supply parameters (PSRTC)

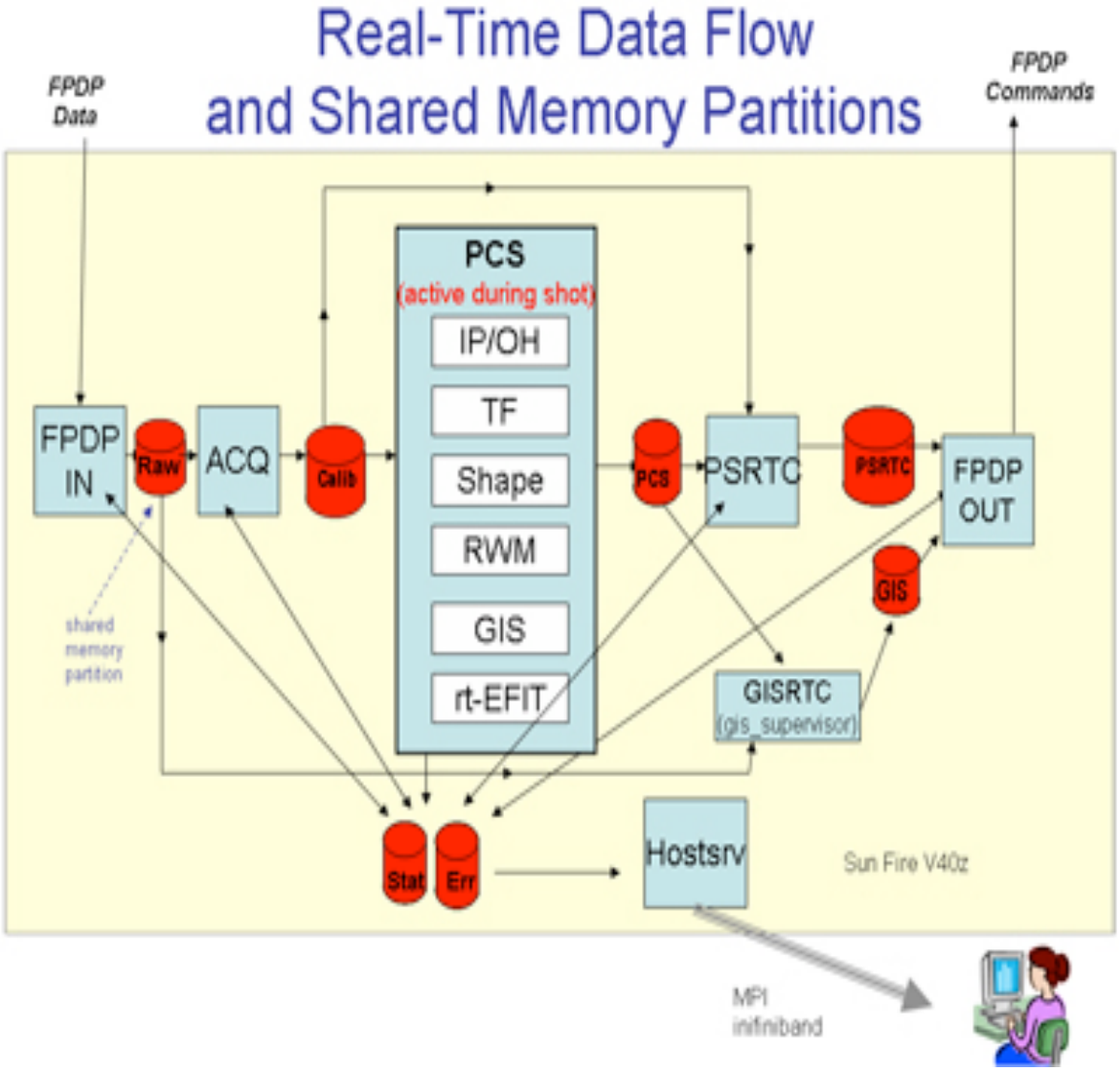
Schedule

- Tested new system in plasma operation at end of 2007 run in June.
  - Replaced SKY routines
  - Added FPDP Output and Digital Time Stamp
  - Discovered a problem in gas system software
  - Fixed and tested gas system off-line summer 2007
- Measured system latency (Nov. 2007)
- Adding archiving and control of PSRTC parameters in MDS plus (January 2008)
- Add NB power control
  - Hardware (November 2007)
  - Software (Spring 2008)

System Diagram

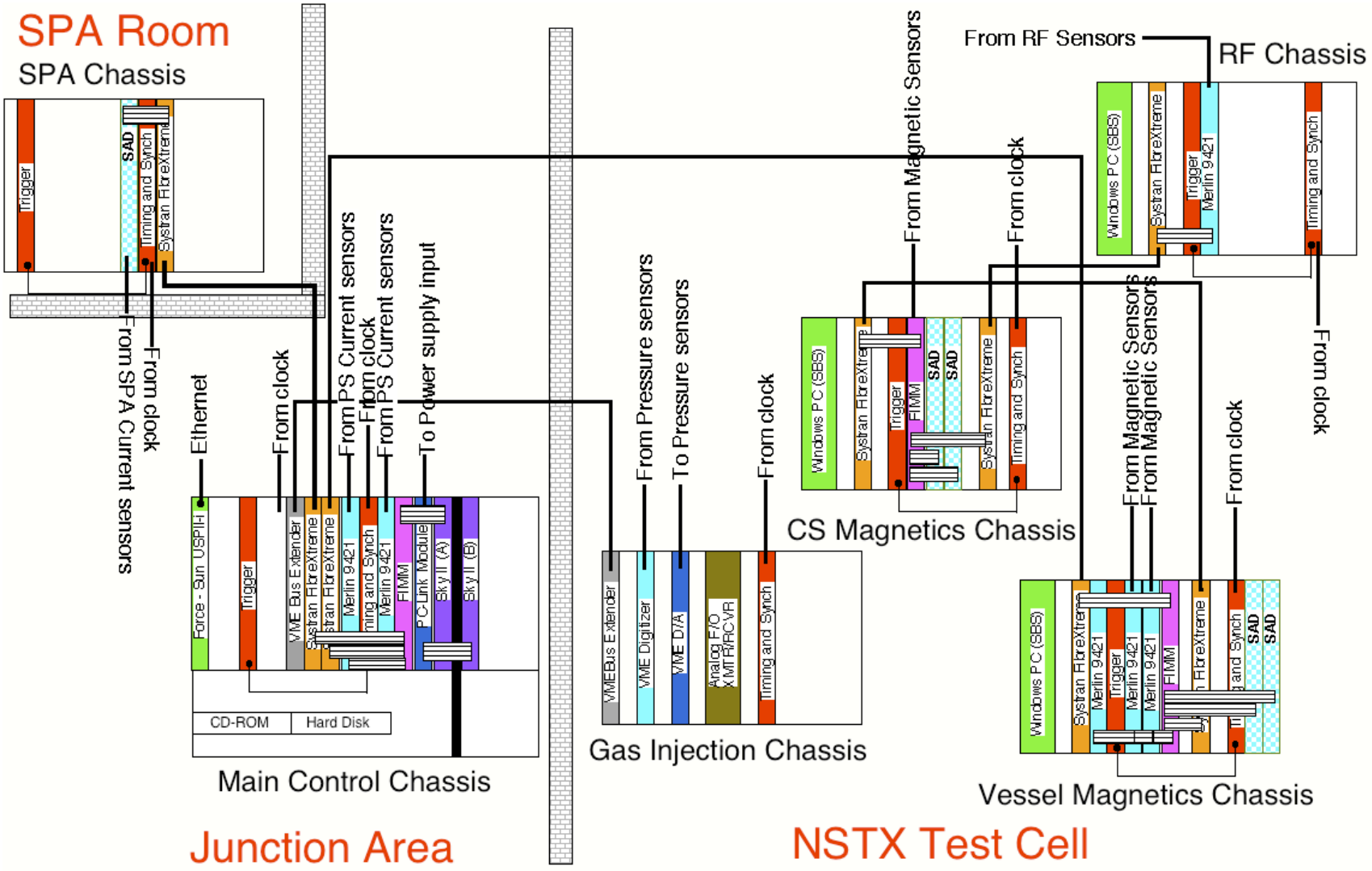


Real-time software control on NSTX



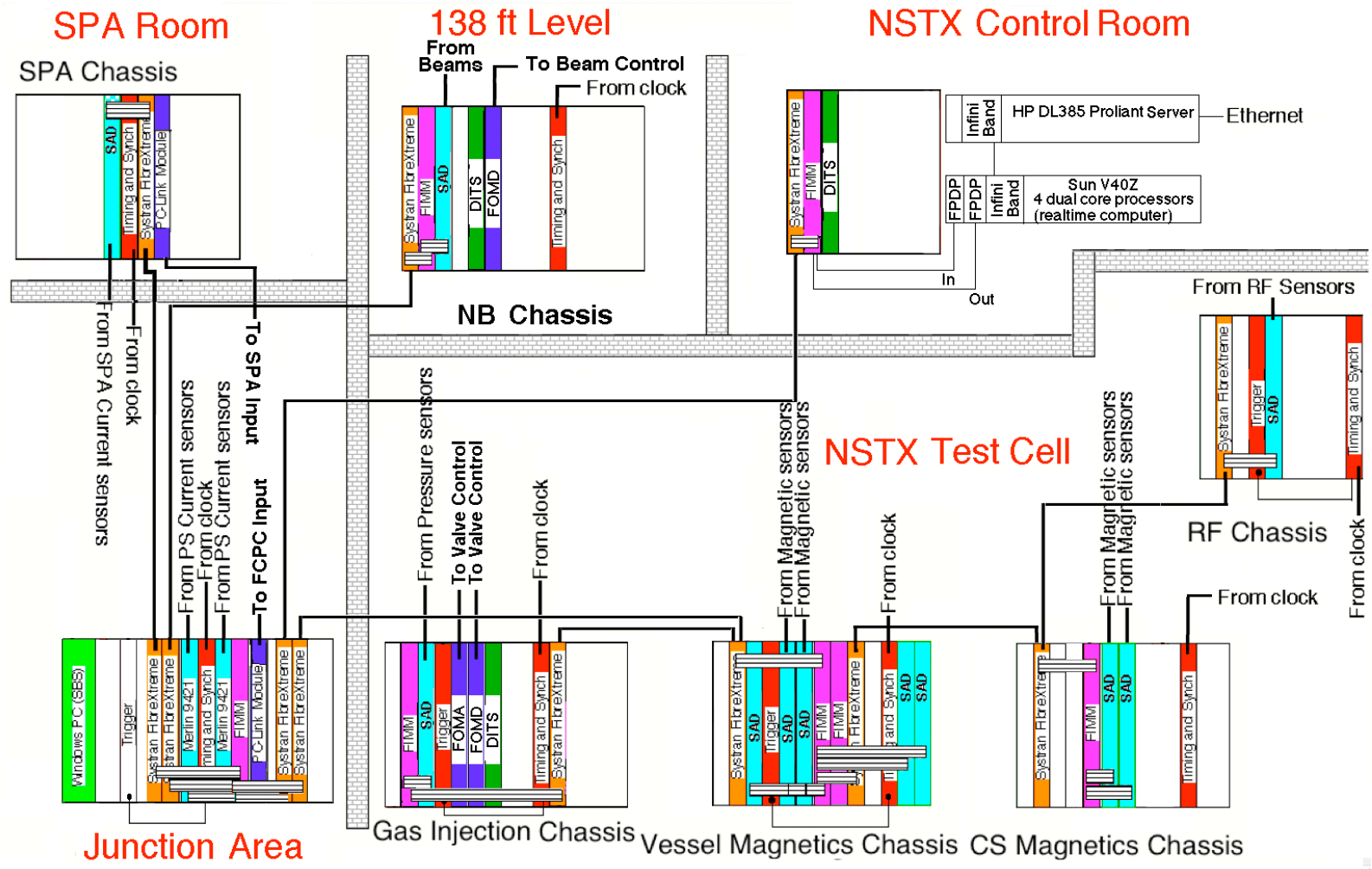
- FPDP_in - retrieves data from the Front Panel Data Port (FPDP) board
- Acq - Reads raw data from shared memory, converts to physical units and monitors time coming from Digital Input Time Stamp module (DITS)
- PCS - calculates power supply request voltages based on PPPL-defined physics models as well as a real-time EFIT approximation.
- PSRTC - applies engineering constraints and converts voltage requests to appropriate output units
- FPDP_out - passes commands from the PSRTC out the FPDP board.
- Hostsrv – system monitoring and reporting of status and error information.

Block diagram of I/O system 2005

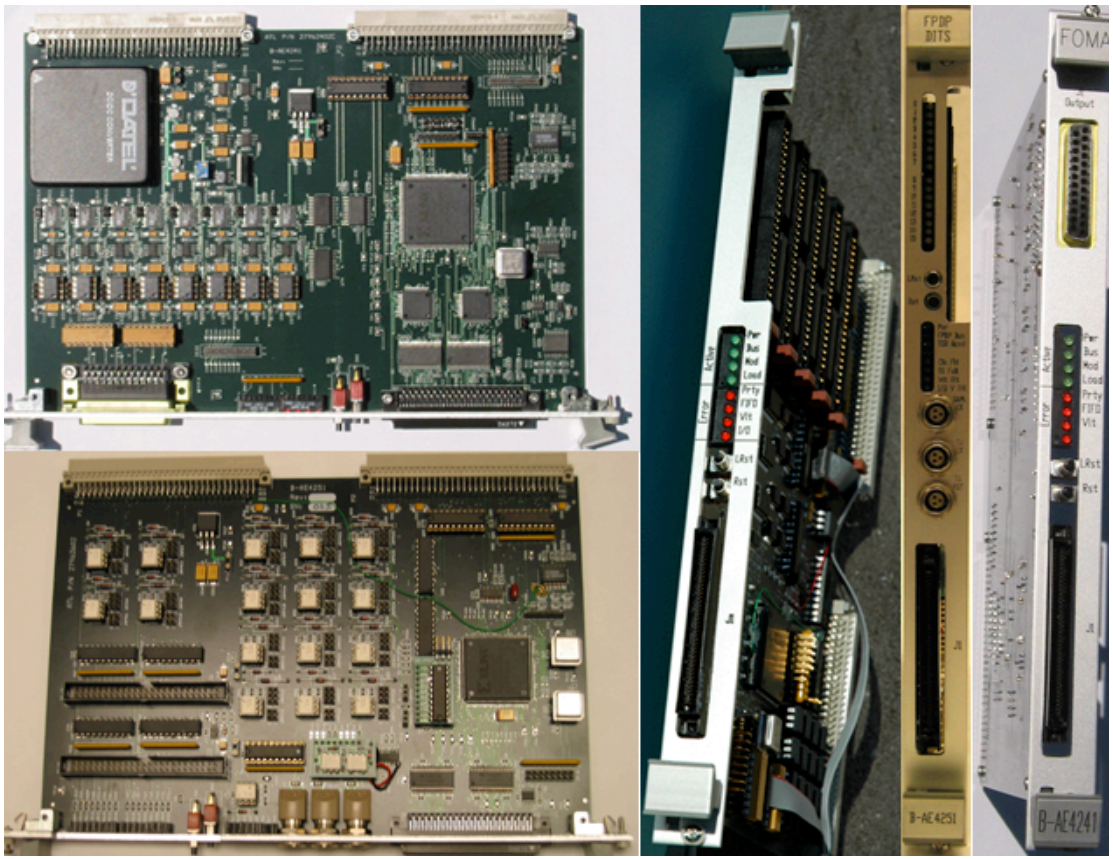


Block diagram of new I/O system

- New computer in NSTX Control room, added NB control



New custom hardware provides data time stamp and FPDP standard output



- Designed, built, tested and installed a Digital Input and Time Stamp Module (DITS)
  - Forty-eight bit time relative to NSTX shot clock in μs for each input data sample
  - Removes reliance on software generated time
- Designed, built and tested 8 channel FPDP Output Module Analog (FOMA)
- Designed, built and tested 64 bit FPDP Output Module Digital (FOMD)

Module Functions

- FIMM, FPDP Input Multiplexing Module, combines multiple FPDP streams by concatenation
- Systran FibreXtreme, serial FPDP data transmitter and receiver (1 Gbit/s fiber optic)
- Merlin 9421, 12 bit FPDP 32 channel transient digitizer
- SAD, 32 channel FPDF Stand Alone Digitizer
- PCLinkModule, converts output data to digital format required by rectifiers

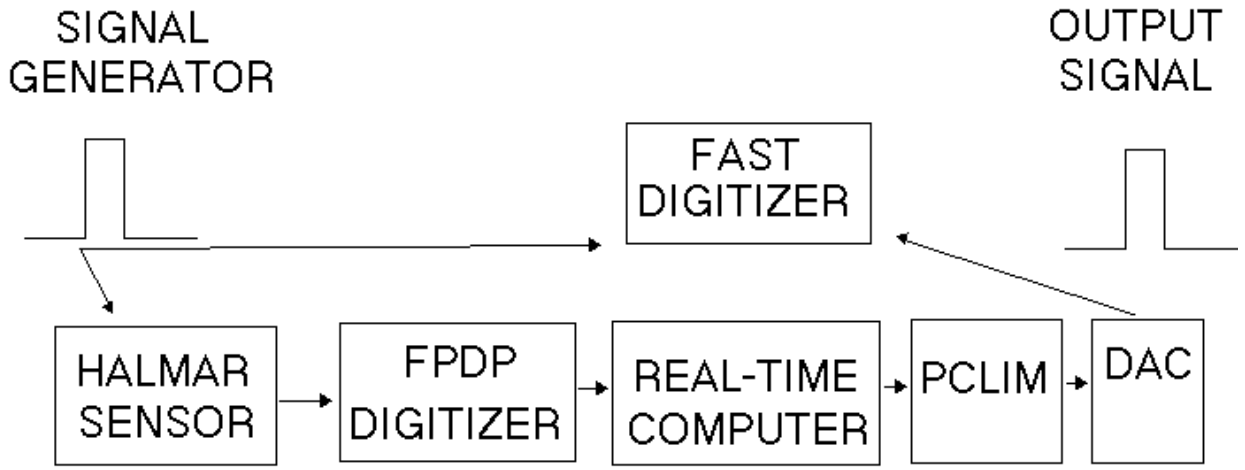
Comparison of computers

- New real-time computers ~ 8 times the processor speed
  - Sun Fire V40z with four dual-core 2.4 GHz AMD Opteron-880 processors
  - replaces the SKY system with eight 333 MHz G4 processors
- Host computer
  - HP DL385 Proliant Server running Linux
  - Replaces the Force workstation that ran the Solaris operating system

New I/O easier to add

- FPDP output hardware modules and software drivers are now fully tested.
- Gas Injection system is now controlled by FPDP I/O rather than slower VME.
- Addition of NB power control is facilitated by use of new FPDP Output modules.

System latency

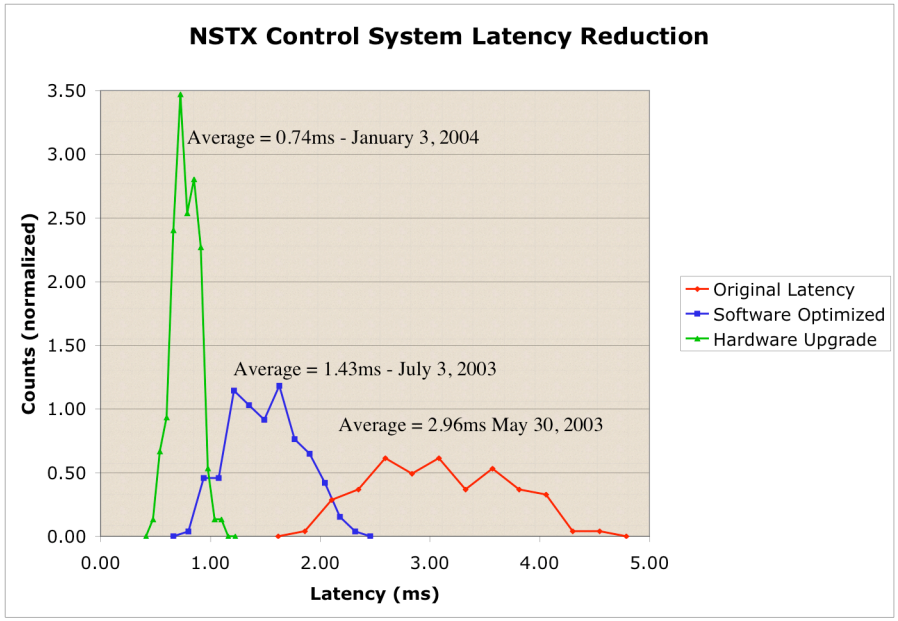


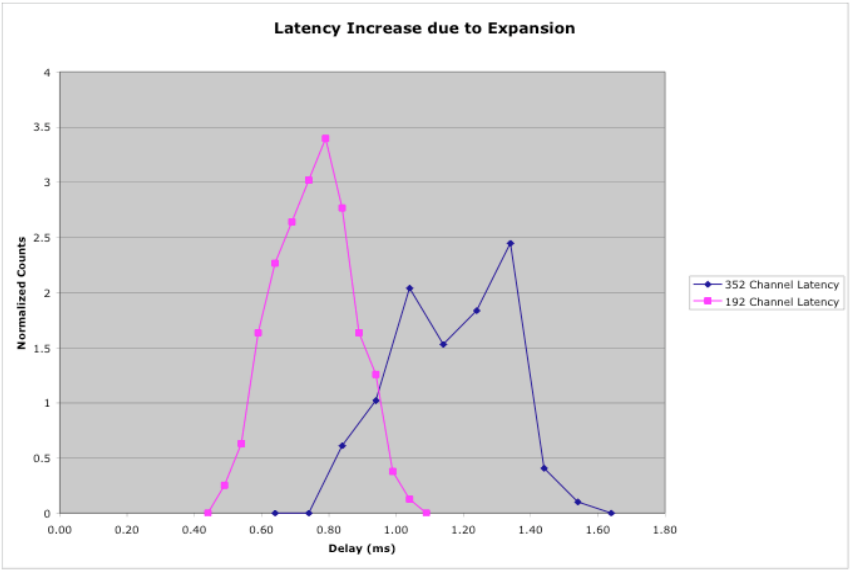
- Measured the delay between a change in an input signal (OH) and the digital output to control the power supplies.
- This includes the delays introduced by the data conversion, internal computer data transfer, data handling, calculations and conversion to a digital firing angle for the power supplies.
- It does not include delays due to sensors, power supply response time or the software slew rate limit (the latter was removed for this test).

Progress in reducing the system latency

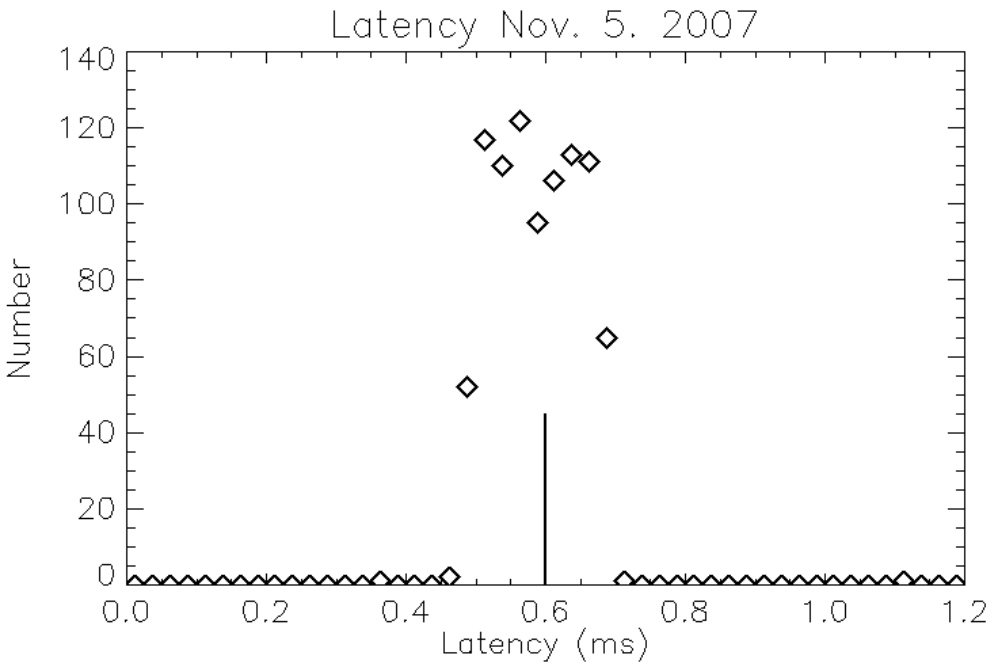
- In 2003 and 2004 efforts to reduce the latency resulted in a reduction from 3 ms to .74 ms with 192 data channels

In 2005, the number of data channels was ~ doubled to 352 channels, increasing the latency to 1.2 ms





Present latency reduced to 0.6 ms with 384 channels



- Presently, the data acquisition rate of 5 kHz results in a spread of 0.2 ms in the latency measurement.
- Using a faster digitization rate would reduce latency by 0.1 to 0.2 ms.
- Identifying other delays in the system may result in further reduction.

Summary

- Replaced computers running obsolete operating systems
  - New real-time computers are 8X faster
  - Slow VME in gas system was replaced with FPDP
- Upgraded system used for plasma control test in June.
- Measured system latency was reduced from 1.2 to 0.6 ms with further reduction possible.
- New FOMA and FOMD provide FPDP outputs to facilitate control of additional subsystems.
  - First use for gas system
  - Neutral Beam Power control next spring
- Archival and restoration of engineering constraints (PSRTC) added for 2008 run.