FIRST TEST RESULTS OF THE NEW LANSCE WIRE SCANNER*

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Abstract

The Beam Diagnostics and Instrumentation Team (BDIT) at Los Alamos National Laboratory's LANSCE facility is presently developing a new and improved wire scanner diagnostics system controlled by National Instrument's cRIO platform. This paper describes the control system's current state of development along with the results gathered from the latest actuator motion performance and accelerator-beam data acquisition tests.

INTRODUCTION

The beam diagnostics team at Los Alamos National Laboratory's LANSCE facility is presently developing a wire scanner prototype for the LANCE linear accelerator. This wire scanner system consists of a new actuator design[1], new cable plant, and new data acquisition and control electronics. On December 21, 2010, the prototype system was given its first in-situ test. The following paper describes the highlights of this test with an emphasis on the controller design and performance.

CONTROL SYSTEM OVERVIEW

The controller chassis consists of a 4U, rack-mountable, enclosure containing a NI compact Reconfigurable Input/ Output (cRIO) control system. The test system utilizes the NI Shared-variable-based network communications API to communicate with the client PC. Military connectors at the rear of the chassis provide connectivity to the wire scanner actuator cabling. What follows is an overview of the Controller's Hardware and Software.

Control System Hardware

The core of the wire scanner controller consists of a National Instruments cRIO-9024. Within the cRIO-9024 reside several subsystems: a real-time computer, a FPGA, and various I/O interface modules. Individual I/O interface modules include:

- A Custom analog frontend electronics (AFE) module for horizontal and vertical wire signal transimpedance conversion, continuous-time pre-processing, and signal conditioning output for ADC acquisition of the beam-wire interaction [2].
- A NI 9222 500 kS/s ADC for simultaneous, high-speed sampling of the AFE's output.
- A NI 9401 digital I/O for control of the stepper motor driver and beam gate detection.
- A NI 9485 solid-state relay module for wire bias control.
- A NI 9422 24V logic digital I/O for actuator limit switch input.
- A NI-9870 RS-232 module for communication with a touch-panel display.
- A Micro-Research Finland event receiver (not utilized for this test).
- A RDK-9314 resolver interface measurement of the actuator displacement.

With the exception of the beam synchronization and touch panel interfaces, the aforementioned modules serve as the interface between the cRIO's FPGA and the wire scanner actuator. A diagram and picture of the controller's module configuration is detailed in figure 1.

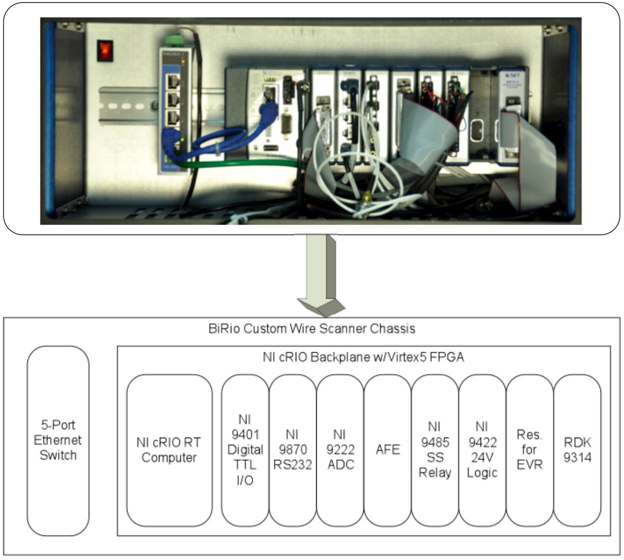

Figure 1: Controller internals

Control System Software

In order to operate, the cRIO controller requires code for two of its subsystems. The first of these systems is the on-board FPGA. Since the FPGA functions as the interface between the RT computer and the modules, it was designated and programmed with the data acquisition and motion control tasks. The RT computer was designated with data analysis, client communication, and FPGA command tasks.

With the data acquisition capabilities provided by the cRIO hardware, new techniques for data acquisition were utilized. The first of these was a digital integrator for calculating charge from the current-relative, AFE signal. The primary benefit of this technique was the ease in which a digital amplifier's state can be zeroed. This was necessary since analog circuits have time constants associated with their use of reactive components (e.g. capacitors and inductors). In some cases, we've considered, these time constants can exceed the time between beam pulses causing resulting in the negative effect where past macropulse data affects subsequent

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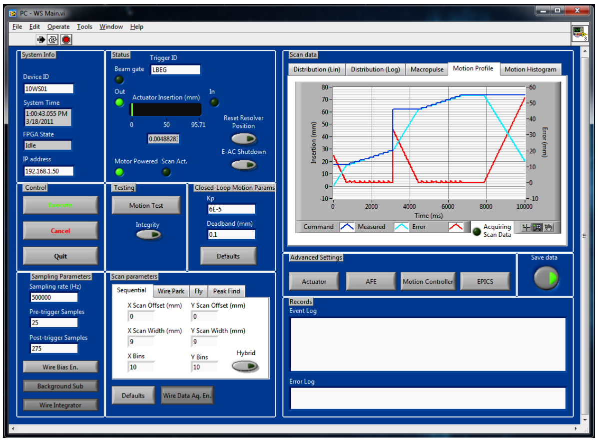
macropulse data. A second data acquisition technique involved the incorporation of continuous sampling. Continuous sampling was performed with a circular buffer. This technique provided the controller with the capability to acquire a finite amount of beam data prior to the rising-edge of the beam trigger. This allowed us to observe how well synchronized the beam arrival was relative to the controller's beam trigger. The circular buffer contains a 600 microsecond (300 sample) window of the macropulse (25 pre-trigger samples, 275 post-trigger samples) which further allowed us to complement the spatial beam data (i.e. beam profile data) with temporal beam data (i.e. macropulse data). A final benefit of the continuous sampling technique was that it also provides information such as background signal data. One instance in which this was useful was for recording the undesirable DC offset signal output from the AFE. DC offsets corrupt the calculation of the digital integrator mentioned previously. For this test, a background subtraction technique was developed that functioned by extracting a specified, contiguous set of values from the macropulse buffer, averaging the values, and then subtracting the result from the macropluse array.

TEST GOALS

A goal of this test was to acquire beam profile measurements for Long Bunch Enabled Gate (LBEG) type beam pulses and observe the overall operation of the prototype wire scanner system. The LBEG beam pulse consists of H- particles and is characterized by a 625 microsecond pulse width repeated at 4Hz.

Another goal of this test was to operate the system in a manner as similar as possible to the final design. Achieving this goal involved deploying the LabVIEW software to the cRIO and communicating to the cRIO controller via Ethernet from a client PC. The intention of this was to emulate a wire scan as commanded from an operator within LANSCE's central control room. The screen capture shown in figure 2 details the control panel utilized by the client PC for operating the wire scanner.



Device ID: 10WS01
System Time: 1:00:43.055 PM 3/18/2011
FPGA State: Idle
IP address: 192.168.1.50
Trigger ID: LBEG
Actuator Insertion (mm): 0.0048828
Kp: 6E-5
Deadband (mm): 0.1
Sampling rate (Hz): 500000
Pre-trigger Samples: 25
Post-trigger Samples: 275
X Scan Offset (mm): 0
Y Scan Offset (mm): 0
X Scan Width (mm): 9
Y Scan Width (mm): 9
X Bins: 10
Y Bins: 10

Figure 2: A screen capture of the PC client program similar to that used on the December 21, 2010 test.

HARDWARE CONFIGURATION

This test involved mounting the 4U controller into the accelerator equipment rack containing the interface cables to the wire scanner. A 5-port 10/100 Mbps switch was utilized to create a small network linking the wire scanner controller to a client PC. Cables within the rack linked the wire scanner control chassis signals with the wire scanner actuator in the beam line. The latest LabVIEW RT and FPGA programs were deployed to the non-volatile memory of the controller and a compiled LabVIEW executable program was deployed to the client PC. Observe figure 3 to obtain a simple visual understanding of the signal interfaces.

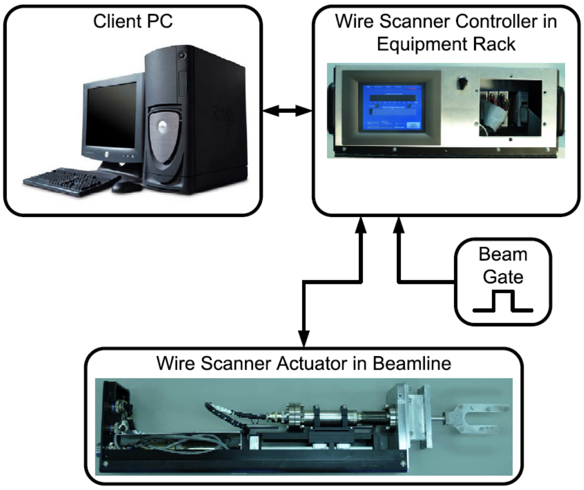


Figure 3: Hardware Configuration.

BEAM DATA ACQUISITION RESULTS

The data in figure 4 shows the result of one of the LBEG beam profile scans.

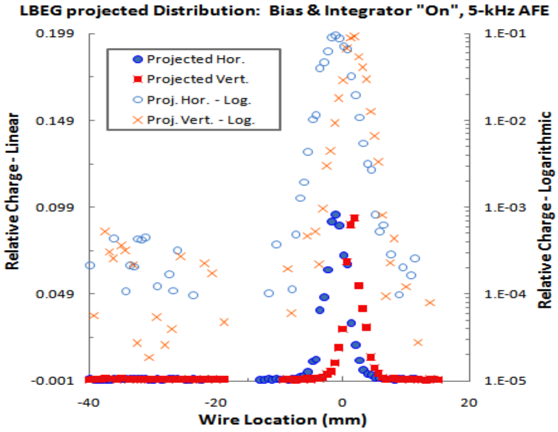


Figure 4: LBEG-gate beam profiles for horizontal and vertical axes.

As can been inferred from the data, the desired, Gaussian-shaped profiles were obtained. The gaps in the data are the result of the controller's independent scanning motion for each axis. This was caused by the controller scanning in the vertical axis first, moving forward a distance during which no profile data was taken, and then scanning the horizontal axis. Although the motion was independent for each axis, beam profile data was taken simultaneously. The purpose of this was to determine whether or not the wire signal coupling phenomena described in [3] would manifest itself in this design. As can be seen from the flat area of data ranging from -40 mm to about -20 mm, no wire coupling is evident. All in all, the results show that the control system performed its intended function adequately and the expected beam profile acquisition result was obtained.

ACTUATOR MOTION PERFORMANCE RESULTS

Figure 5 details a 10-second window of the closed-loop, actuator motion for the scan in figure 4. The red x's represent the commanded positions (or scan bin locations) with smaller blue dots representing the path the actuator actually travelled. The large blue circles indicate the convergence of the measured position to the commanded position resulting in a position error converging to the target band below 0.1 mm. This data generally indicates that the closed-loop motion controller performed well with regard to positional accuracy. Unfortunately, the control system did not drive the actuator to subsequent bin locations within the desired time frame of 0.25 ms.

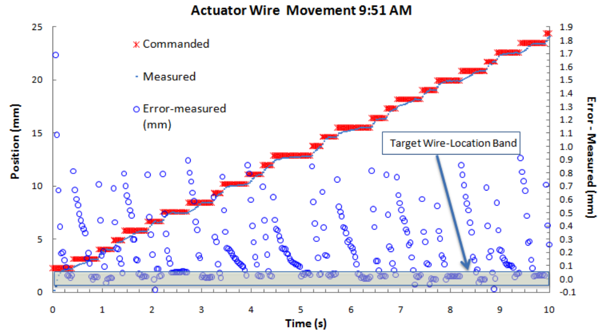


Figure 5: Scan motion data for LBEG

FUTURE WORK

Since the wire scanner control system design is not fully complete, additional features have yet to be developed and tested. These features include interfacing the wire scanner control system to the new Event Receiver-based (EVR) timing system, implementation of EPICS process variables, and the interface to a second actuator design [1]. Also, as the test did not meet the goal of synchronizing the actuator motion with the beam repetition rate, the next in-situ test will be used to explore the solution. Recent work conducted after the December 21, 2010 test has overcome this problem by reducing the communications overhead between the cRIO RT computer and the client PC. Figure 6 shows the latest scan capability of the wire scanner with excellent 4Hz beam synchronization. The control pattern created by the position generator is such that an initial position is commanded, then a step motion is used to scan the vertical profile, then the actuator moves directly to an initial position for the horizontal profile, a step motion is used to scan the horizontal profile, and then the actuator returns to the home position or zero. For figure 6, the scan parameters where set for 10 bins per axis, no position offset (a centered scan), and a scan width of 9mm for each axis (value scaled in figure 6 for a 45-degree actuator placement). Wire centers are located at 23.47mm and 68.37mm for vertical and horizontal wires, respectively.

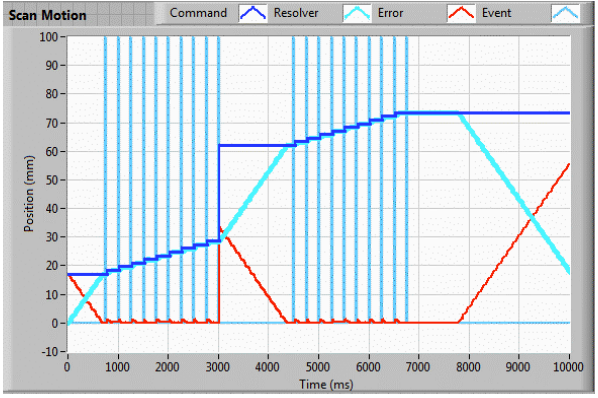


Figure 6: Well synchronized scan motion.

The dark blue line represents the commanded position and the teal line represents the resolver-measured position. As intended, the measured position converges to the commanded position. The red line represents the error or difference between the commanded and measured positions and converges to zero for each bin position. The light blue vertical spikes represent 4Hz beam gate events. The correlation of the motion with the beam gate indicates that the actuator is moving to a new bin position every 250ms and thus will be well synchronized with the arrival of the following macropulse. In this case, the latest control software will be capable of synchronizing the wire scanner motion to the 4 Hz macropulse repetition rate.

REFERENCES

[1] S. Rodriguez, et al., "LANSCE Wire Scanning Diagnostic Device Mechanical Design," PAC '11 New York, March 2011 MOP235; http://www.JACoW.org.

[2] M. Gruchalla, et al., "LANSCE-R Wire-Scanner Analog Frontend Electronics (AFE)," PAC '11, New York, March 2011, MOP232; http://www.JACoW.org.

[2] A. Alexandrov, "The SNS Beam Diagnostics Experience, Lessons Learned and Plans," BIW '10, Santa Fe, May 2010, MOIMNB02; http://www.JACoW.org.