# THE SNS LINAC WIRE SCANNER SYSTEM*

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*Abstract*

The linac wire scanner system for the Spallation Neutron Source (SNS) at Oak Ridge, TN, calls for 5 units in the medium energy beam transport (MEBT), 5 in the drift tube linac (DTL), 8 in the coupled cavity linac (CCL), and 13 in the high energy beam transport (HEBT). The actuators are a custom design fabricated by Huntington Mechanical Laboratories. Four different strokes are required to cover the above areas. The electronics are designed and fabricated by Los Alamos National Laboratory (LANL). In this paper we will discuss the design of the actuators and the electronics, positioning accuracy tests of the actuators, and also show results from beam measurements taken during the MEBT commissioning at Oak Ridge National Laboratory.

## OVERVIEW

In the Spallation Neutron Source (SNS) facility, $H^-$ beams will be accelerated to 2.5 MeV in an RFQ, to 87 MeV in a drift tube linac (DTL), to 186 MeV in a coupled cavity linac, and finally to 1000 MeV in a superconducting linac (SCL). The 60-Hz, 1-ms, 36-mA peak-current beam pulses are chopped into 690-ns long segments with a 1 μs period to give an average current of 1.4 mA and an average beam power of 1.4 MW.

Linac wire scanner systems are installed in the MEBT (5 units), the DTL (5 units), the CCL (8 units), and the HEBT (13 units). Similar actuators but different signal processing electronics are used in the ring and ring-to-target beam transport (RTBT) areas.

A pivoting style of actuator was originally developed [1] for the SCL, but for this portion of the linac it was later decided to install laser profile monitors [2] instead. A large part of this decision was based on the concern of broken wire fragments contaminating the super conducting cavities.

## ACTUATORS

The wire scanner actuators in the DTL, CCL, and HEBT areas are based on custom-designed linear actuators from Huntington Mechanical Laboratories, Inc. Three carbon wires, 32 microns in diameter, are mounted to each wire scanner fork to measure the beam profile in three different planes. The wires are offset from each other so that no more than one wire at a time is within ±2 rms of the beam center. A special collet design, developed at LANL, is used to hold the wires in place with a small amount of tension to accommodate thermal expansion and contraction.

The stroke of the DTL actuators is 6 inches, for the CCL it is 3 inches, and for the HEBT it is 8 inches. The actuators are fabricated using bellows rated for 50,000 cycles to accommodate the 30,000 cycle estimate of the maximum number of cycles over the 30-year lifetime of the facility. Radiation-hardened coaxial connectors and linear variable differential transformer (LVDT) position read back devices are also used to accommodate the $10^5$ Gy estimate of the maximum dose to an actuator over the same facility lifetime.

Each actuator also has a brake and five limit switches. One limit switch at each end is for motion control, two redundant limit switches in series at the retracted end are for the machine protect system, and the last limit switch, at the inserted end, is provided for potential future purposes. Each actuator, including the fork and the collet wire mounts, costs about $6,500. A photograph of a DTL actuator is shown in Fig. 1.

Fig. 1. (color) Photograph of a 6-inch stroke actuator.

Although carbon wires can withstand higher beam intensities than other wire types, the linac duty factor must still be reduced when using the wire scanners. The linac beam parameters are expected to stabilize after about 30 μs, and so a beam pulse length of about 50 μs is a minimum requirement for the wire scanner systems. For the nominal beam current of 26 mA average, the carbon wires will remain below the 1225 $^{o}$C temperature limit [3] (needed to avoid signal contamination due to thermionic emission) as long as the beam pulses are less than 50 μs long and the repetition rate is 10 Hz or less, in all areas

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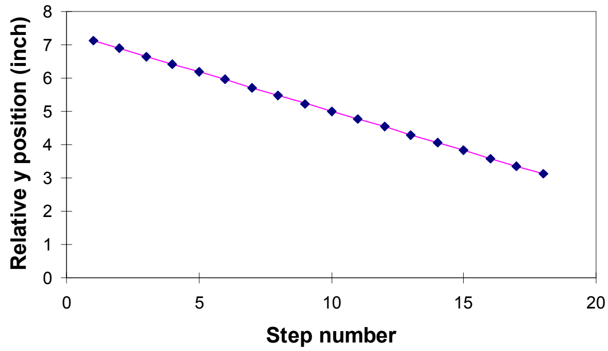


Fig. 2. (color) Measured position of the 6-inch prototype actuator vs. step number.

except the MEBT, where the repetition rate limitation is 1 Hz.

Of course actuator positioning accuracy is a critical component of the accuracy of a beam size or beam position measurement [4]. The SNS requirement is to measure the rms beam size with an accuracy of 10% or better. To meet this requirement, assuming a relative electronic signal processing error of 1%, an absolute signal processing error of 2% of the maximum signal, and no beam jitter, the DTL actuator positioning error should be less than 0.4 mm, and the CCL actuator positioning error should be less than 0.3 mm [4].

We measured the positioning errors of the prototype DTL and CCL actuators by mounting the actuators in the vertical orientation and suspending a 5 kg weight from each actuator to simulate the vacuum load. Each actuator was moved in a series of equal-length steps by issuing a certain number of pulses to the stepper motor for each step. After each step we used two theodolites to measure the horizontal and vertical positions of an alignment target mounted to the ends of the actuators. Before making any of these position accuracy measurements we cycled each actuator more than 2000 times with the 5 kg weight attached. Shown in Fig. 2 is the plot of the measured actuator position vs. the number of pulses issued to the stepper motor on the 6-inch actuator. The result [5] is an effective positioning accuracy of 0.11 mm for the 6-inch DTL actuator, and 0.15 mm for the 3-inch CCL actuator.

## ELECTRONICS

The electronics package consists of an 4.4-cm tall (1U) signal processor chassis, an 8.9-cm tall (2U) driver chassis, and a 17.8-cm tall (4U) rack-mounted PC. A block diagram is shown in Fig. 3.

The signal processor has several functions: 1) it applies a high voltage bias (up to 100 V) to the wire scanner wires; 2) it detects broken wires by sensing a change in the voltage drop due to the 180 kΩ resistors electrically connected to the opposite ends of the signal wires and mounted directly to BNC connectors on the actuators; 3) it ac-couples the wire signals to current-to-voltage converters with three gain ranges; 4) it delivers the 36-kHz bandwidth-limited signals to the National Instruments PCI-6110 data acquisition card in the PC; and 5) it contains a software-controlled built in self test circuit that injects a test pulse into the front end circuitry. The

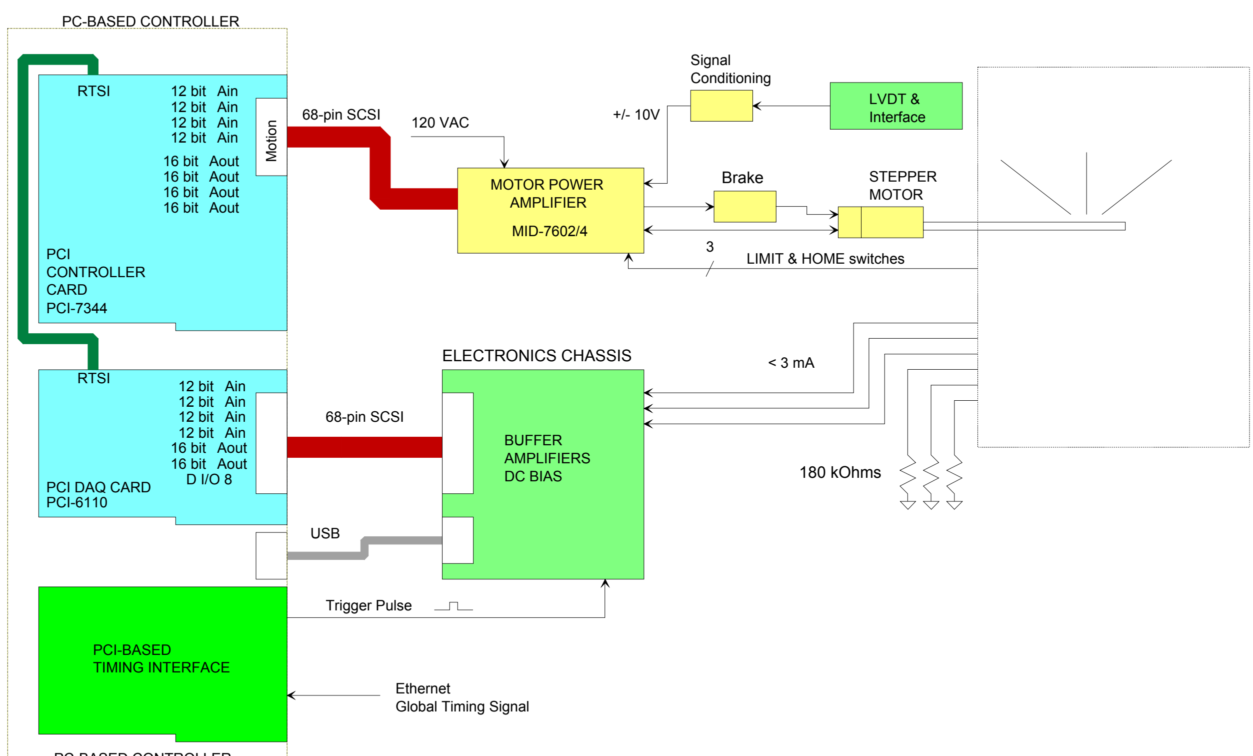


Fig. 3. (color) A block diagram of the linac wire scanner system.

signal processor chassis also employs a LabJack© U12 module to monitor critical system voltages and send the results to the PC via a USB port on the PC. Some measured specifications are shown in Table 1, and a photograph of the signal processor chassis is shown in Fig. 4.

Table 1. Signal processor specifications.

| | |
|---|---|
| Minimum signal | 16 nA at high gain |
| Maximum signal | 2.1 mA at low gain |
| No. gain ranges | 3, separated by 18 dB |
| Linearity | <0.004% of full scale output |
| Rise/fall time | 8 µs |

The driver chassis interfaces to the National Instruments PCI-7344 motion control card in the PC and controls the stepper motor and the brake via the National Instruments MID-7602 stepper motor driver module. The chassis also contains the Macrosensors LVC-2401 signal conditioner for the rad-hard Macrosensors PR-750 series LVDT mounted on the actuator. Although the LVDT linearity specifications are quite good (<0.25% of full range), it does not measure the actuator position as accurately as simply counting the pulses issued to the stepper motor. Its function is therefore limited to checking that the actuator is operating properly.

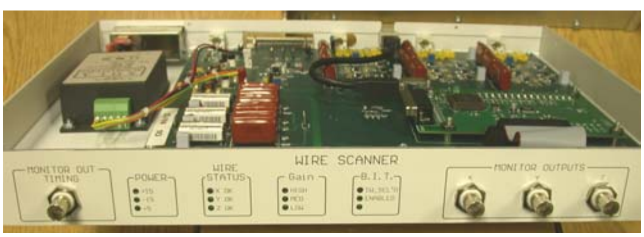


Fig. 4. (color) Photo of the signal processor chassis.

A second type of driver chassis has been designed based on the Phytron CLD 20-24 linear stepper motor driver. The two types of chassis have been designed to be functionally equivalent, however we expect that the linear stepper motor driver will produce less electromagnetic noise than the MID-7602 chopper driver. The two chassis types will be tested in the realistic beam environment during the coming year, and then a down select decision will be made.

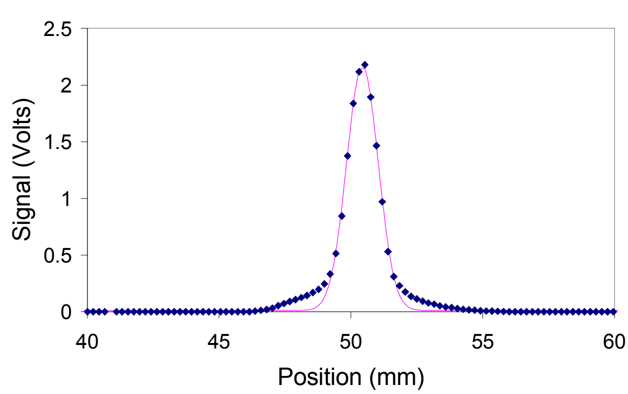


Fig. 5. (color) A sample wire scanner measurement taken in the SNS MEBT.

The rack-mounted PC contains three PCI cards: 1) a National Instruments PCI-6110, 4-channel, 5-MS/s, 12-bit data acquisition card; 2) a National Instruments PCI-7344 motion control card; and 3) a custom-made PCI timing card to interface to the SNS global timing system. We've chosen to use either embedded Windows 2000 or Windows XP for the operating system, LabVIEW for the data acquisition and motion control software, plus some custom-designed software to allow each PC to appear to the EPICS control system as an Input-Output Controller (IOC).

## PERFORMANCE

The electronics were first installed in the MEBT portion of the SNS linac together with the MEBT actuators (not described in this paper) developed by Brookhaven National Laboratory. The first measurements with beam were made in February 2002 at Lawrence Berkeley National Laboratory. A sample profile measurement from the recent Winter 2002-3 commissioning period at ORNL is shown in Fig. 5. The data are smooth and well described by a Gaussian fit to the core of the beam. The measured beam sizes also agree well with optics models of the MEBT and with laser profile measurements made concurrently with the wire scanner measurements.

Two more wire scanner systems, for the first DTL tank and the D-plate, have recently been installed, and in the next year we will install the remainder of the DTL and CCL systems. The HEBT system installations will take place in summer 2004, and this will complete the linac wire scanner system installation.

## REFERENCES

[1] R. Hardekopf et al., "Wire Scanner Design for the SNS Superconducting-RF Linac," Proceedings of the 2001 Particle Accelerator Conference, Chicago, Ill, June 18 – 22, 2001.

[2] R. Connolly et al., "Laser Beam-Profile Monitor Development at BNL for SNS," proceedings of the 2002 Beam Instrumentation Workshop, Upton, NY, USA, 6 – 9 May 2002.

[3] J.D. Gilpatrick, private communication.

[4] M. Plum, W. Christensen, R. Meyer, and C. Rose, "SNS Linac Wire Scanner System: Signal Levels and Accuracy," Proceedings of the LINAC 2002 conference, Gyeongju, South Korea, August 19-23, 2002.

[5] M. Plum, "SNS Actuator Position Accuracy Tests," Jan. 31, 2003. SNS Tech Note 104050204-TR0001-R00.