BRIDGING THE GAP; UPDATING LANSCE DIGITIZERS*

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Abstract

The Los Alamos Neutron Science Center (LANSCE) is currently upgrading equipment that is used to digitize transverse beam profile measurements. Emittance measurements were originally digitized using legacy equipment, known as RICE (Remote Indication and Control Equipment). This required 38 RICE modules distributed along the half-mile long accelerator simultaneously recording 4 channels each to populate the 76 data points needed to create a single emittance profile. The system now uses a National Instruments cRIO controller to digitize the entire profile in a single chassis. Details of the hardware selection and performance of the system for different timing structures are presented.

INTRODUCTION

LANSCE is a National Research Facility which contains a half-mile-long linear accelerator. (LINAC). The LANSCE LINAC creates proton beams with energies up to 800 million electron volts and is capable of accelerating protons to 84% the speed of light. LANSCE achieved full energy on June 9, 1972 and continues to run to this day with much of its late 1960's – early 1970's technology intact.

An example of this late 1960's technology is the data acquisition and control system for the LANSCE LINAC better known as RICE (Remote Indication and Control Equipment).

RICE

RICE was custom built as part of the first large-scale effort to use computers to control an accelerator. Designed in the late 1960's, before CAMAC and VME standards, it was created to provide control and data readout (industrial I/O) for most devices in the LANSCE LINAC. Its architecture was designed to directly map onto the architecture of the LINAC and thus is tightly coupled to the LINAC hardware.

An average RICE module contains 30 analog inputs, 50 digital inputs, 8 analog commands and 30 digital command channels. There are 66 RICE modules distributed along the LANSCE LINAC.

The layout of the LANSCE LINAC is illustrated in Figure 1 (individual RICE modules are represented by circled numbers). The 66 RICE Modules are connected to one uVAX computer in a star topology configuration.

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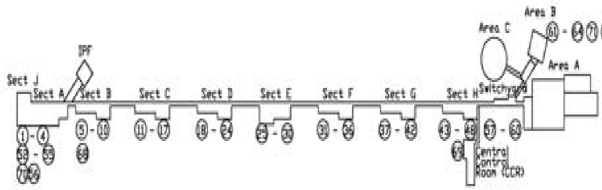

Figure 1: LANCE LINAC.

A RICE module consists of three separate components: the RICE chassis, the RICE Input/Output (I/O) chassis and the Analog Data System (ADS) chassis. The RICE chassis is a serial to parallel and parallel to serial word encoder/decoder. The RICE I/O chassis is used to interface the RICE system with the accelerator inputs/outputs and can address up to 128 binary channels. The ADS chassis is a 128 channel differential A/D converter used for analog readback of accelerator devices [1].

EMMITTANCE (RICE)

Beam emittance at LANSCE was originally obtained by utilizing 4 analog data point channels on 38 separate RICE modules. These RICE modules simultaneously record the data to produce the 76 data points needed for a single emittance profile. The data points (12-bits) were generated by inserting a 20 mil copper slit and a 76 wire collector with 1 mm pitch into the beam line and simultaneously recording data on each of the wires as it passes through the beam.

The EMRP (EMittance Replay Program) software program plots the emittance data with amplitude as a function of position and collector wire index. The data in the plot is correlated by the same time offset from the beginning of the beam pulse. In order to observe beam behaviour in different points of time along the beam pulse, the hardware triggering offsets need to be changed and scans retaken. This process can take upwards of 8 hours to collect longitudinal measurements across the pulse.

Currently LANSCE utilizes six Emittance systems:

- IBEM – H- Injector
- TAEM – H+ Transport
- TBEM – H- Transport
- TDEM – Low Energy Beam Transport
- TREM – Transition Region Transport
- IDEM – Ion Source Test Stand.

Each system represents a specific beam species in a critical location along the accelerator. These systems are primarily used for beam tuning to detect the position of the beam in the accelerator and to characterize beam quality. An example of a TAEM02 Horizontal emittance scan is shown in Figure 2.

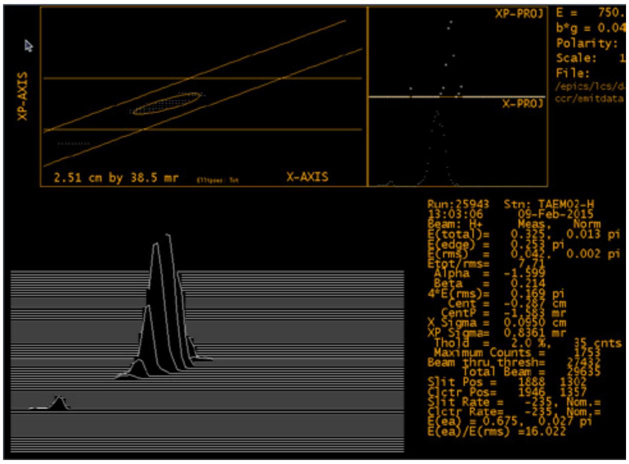

Figure 2: TAEM02 - H Emittance Scan (RICE).

Although this process has been working successfully for decades, the RICE system has become difficult to maintain due to dwindling spares and obsolete replacement parts. The RICE system is currently being phased out and replaced with National Instruments (NI) Compact RIO (cRIO) Programmable Automated Controller (PACS) system (16 bit).

EMMITTANCE (CRIO)

The cRIO system is a reconfigurable control and data acquisition system. It is a high performance system that is very reliable with individual modules Mean Time Before Failure (MTBF) ranging from 37,141 hours. to 2,172,740 hours [2]. It is a commercial modular system that utilizes a variety of hot swappable I/O modules that can be used for a variety of applications.

Requirements

The upgrade task was to create an emittance scan that displayed the same characteristics as the old system to ensure that scans could be used to compare with older documentation. This also presented an opportunity for LANSCE to enhance of the legacy emittance system. The two areas that were improved:

1. The disadvantage of the data acquisition system being distributed over the length of the facility rather than being centralized at the device.
2. The disadvantage that a scan plot is limited to a single time offset from the beginning of the beam pulse.

Chassis Configuration

The NI cRIO system was selected to accomplish these tasks. The cRIO system consisted of the following components:

- NI cRIO-9024 – Real time controller with 800MHz, 512 MB DRAM and 4 GB Storage
- NI cRIO-9118 – 8-slot, Virtex-5 LX110 CompactRIO Reconfigurable Chassis.
- NI cRIO-9401 – 10MHz, 5V TTL logic module.
- NI cRIO-9220 - 16-channel, 100kHz, +/-10V Analog-to-digital conversion modules (x5).

Figure 3: Emittance cRIO Chassis.

Results

The new cRIO system was installed during the 2015 run cycle as a proof of concept for one emittance station. Figure 4 shows a TAEM02 Horizontal emittance scan taken with the new cRIO emittance chassis, confirming the measurement could perform as a direct RICE replacement.

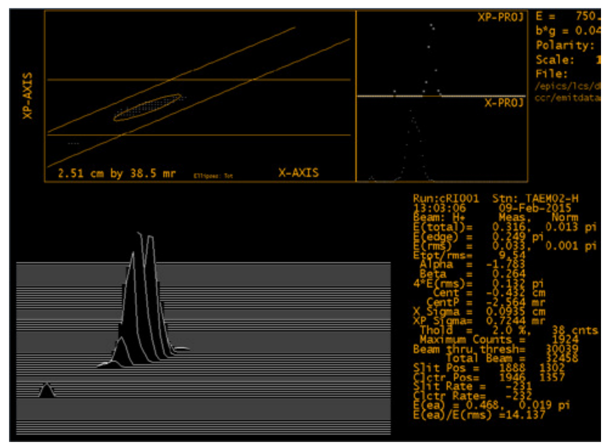

Figure 4: TAEM02 – H Emittance Scan (cRIO).

CONCLUSION

These results demonstrated that the new system was functionally equivalent to the old system, so the cRIO system was installed and has been operating successfully during the 2016 run cycle. The improvements to the emittance system due to the new cRIO systems are:

1. The cRIO system is now located in the two locations were the emittance hardware is located.
2. Data is now recorded at 700 time slices 10usec apart instead of a single time slice which provides more emittance data in a shorter amount of time.
3. The new system allows emittance data to be observed in time. The data can be observed as an animated emittance plot.

Overall the cRIO emittance system is a vast improvement over the RICE system, it is a bridge between the old and the new until a completely new emittance system can be developed.

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