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A Next Generation Digital Counting System for Low-Level Tritium Studies

Since the early seventies, SRNL has pioneered low-level tritium analysis using various nuclear counting technologies and techniques. Since 1999, SRNL has successfully performed routine low-level tritium analyses with counting systems based on digital signal processor (DSP) modules developed in the late 1990s. Each of these counting systems are complex, unique to SRNL, and fully dedicated to performing routine tritium analyses of low-level environmental samples. It is time to modernize these systems due to a variety of issues including (1) age, (2) lack of direct replacement electronics modules and (3) advances in digital signal processing and computer technology. There has been considerable development in many areas associated with the enterprise of performing low level tritium analyses. The objective of this LDRD project was to design, build, and demonstrate a Next Generation Tritium Counting System (NGTCS), while not disrupting the routine low-level tritium analyses underway in the facility on the legacy counting systems. The work involved (1) developing a test bed for building and testing new counting system hardware that does not interfere with our routine analyses, (2) testing a new counting system based on a modern state of the art DSP module, and (3) evolving the low-level tritium counter design to reflect the state of the science.

Awards and Recognition

N/A

Intellectual Property Review

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publically published in its current form.

SRNL Legal Signature

Signature **Date**

A Next Generation Digital Counting System for Low-Level Tritium Studies

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Since the early seventies, SRNL has pioneered low-level tritium analysis using various nuclear counting technologies and techniques. The electronics involved in performing the data acquisition changed dramatically from analog to the digital in 1999. Since then, SRNL has successfully performed routine low-level tritium analyses with counting systems based on digital signal processor (DSP) modules developed in the late 1990s. Each of these counting systems are complex, unique to the National Security Directorate at SRNL, and fully dedicated to performing routine tritium analyses of low-level environmental samples. To maintain the strong position we have had for decades in the low-level tritium analysis area, these counting systems must evolve due to advances in technology. The objective of this LDRD project was to design, build, and demonstrate a Next Generation Tritium Counting System (NGTCS), while not disrupting the routine low-level tritium analyses being performed in the Ultra-Low Level Counting Facility (ULLCF) on the legacy counting systems. The work involved (1) developing a test bed for building and testing new counting system hardware that does not interfere with our routine analyses, (2) testing a new counting system based on a modern state of the art DSP module, and (3) evolving the low-level tritium counter design to reflect the state of the science. The demonstrated system will help keep SRNL on the leading edge of low-level tritium counting.

FY2016 Objectives

- To develop a test bed for evaluating counting system hardware without interfering with the routine analyses underway in the laboratory.
- To design, build and demonstrate a next generation digital counting system.
- To begin evolving the Low Level Tritium Counter design to maintain state of the science and reduce costs.

Introduction

Transitioning the legacy counting systems to NGTCS technology is expected to lower the limit of detection, reduce system noise, increase system stability, lengthen counter longevity, and enhance efficiency of the detector manufacturing process.

Given the success of the low-level digital tritium counting systems at SRNL over the last 15 years, we anticipate that utilizing more modern DSP technology will work well for our application. We have identified a modern DSP module that we believe can replace the critical functionality of the legacy DSP modules and improve on the performance of the legacy systems. In particular, we are hopeful that the new DSP module combined with the expected advances in the design of the low-level tritium proportional counters will have the effect of increasing the overall sensitivity of the analyses with enhanced reliability and cost effectiveness.

The development of a test bed that is separate from the legacy counting systems will make it possible for us to evolve component design and evaluate modern DSP technology under carefully controlled conditions without adversely impacting the routine low-level tritium analyses being carried out on the legacy systems on our customer's behalf. The development of the test bed in the Ultra Low Level Counting Facility (ULLCF) will save money by avoiding the duplication of flammable gas services already available in the laboratory.

Approach

The basic approach was to design and build the test bed and then begin the development of the NGTCS in it. The electronics associated with the NGTCS was then brought into operation sequentially. The first element of the sequence was the installation of the anticoincidence circuit. This involved both the testing of the anticoincidence detectors and their associated signal chain. The second element was the testing of the low level proportional counter circuitry. This testing began with the fabrication of a typical low level tritium counter of the kind used successfully with the existing Low Level Digital Tritium Counting Systems. This counter became the first legitimate signal source for the NGTCS containing real signals with the full complement of typical noise. It was fully anticipated that there would be many difficult days of searching for a set of working parameters for the NGTCS. Once a working set of parameters was developed the slow process of optimizing the set of parameters could begin and the process of assessing new counter designs could move forward.

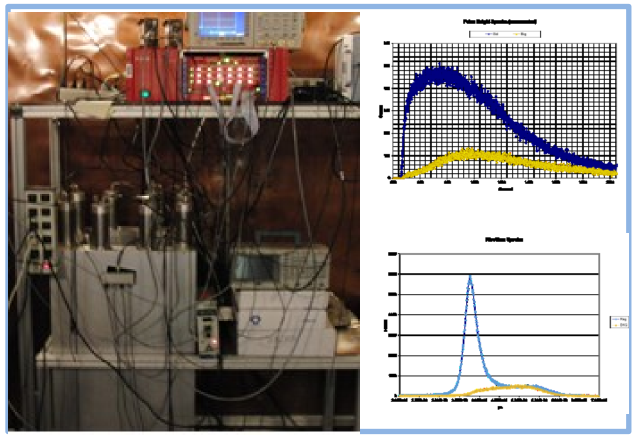

Figure 1. Test bed counting system (left) as installed in the ULLCF. Pulse height (top right) and rise time (bottom right) spectra collected on system using a standard (blue line) and background (yellow line) gases.

The new low level proportional counters were then manufactured, and assembled in preparation for installation in the NGTCS. This process was complicated by the mechanical differences in the materials used to manufacture the experimental end pieces for the new counters. Each counter had to pass a rigorous leak check under vacuum and pressure, and be evaluated for breakdown to be a candidate for installation in the NGTCS. The counters were installed in the test bed with their signals routed to one of the spare legacy DSP modules. In this arrangement we could begin to view the results of our forced evolution of the low level proportional counter design through a familiar lens. This approach was fruitful for investigating the results of evolving the low level proportional counter design, but without additional development of the data acquisition code for the NGTCS only limited testing with the NGTCS was possible.

Results/Discussion

The test bed was completed and the NGTCS was designed, built and brought into operation with the skeletal data acquisition code (Rev. 0) shipped with the digital signal processing module. We expected the skeletal data acquisition code to provide us with only a crude set of tools for operating the NGTCS. As our experience with the new technology accumulated, it became clear that a document specifying the many expected details of the data acquisition code was needed[1]. The skeletal data acquisition code is currently being rewritten using the document.

Two new low level proportional counter designs were tested using a counter of the legacy design as a control. The first trial design had end pieces that were longer than the legacy end pieces. The results with this lengthened proportional counter were so noisy in comparison to the legacy design that it was put aside for further testing. It was finally realized that the longer end pieces had more pick up from the larger portion of the sense wire outside the shielded region. The second trial featured the same overall length as the legacy counters, but a design that considerably reduces the process of preparing a counter from parts for a lifetime of operations. A set of 6 materials were selected for the end pieces of the set of 6 experimental counters, including Duratron, Tivar, Macor, Teflon, Kynar740-1000HD, Kel-F/PCTFE. The Macor parts have not arrived yet, but they are expected and they will be tested when they do. Unfortunately, the results from the Macor trials will certainly not be available for this report. The remaining experimental proportional counters were successfully brought into operation in the time since the midterm report. The new low level proportional counter design will continue to be tested in a number of ways all requiring more time than is left in this LDRD project. Of particular interest to us is the effect of the other materials on the counter's long term behavior. We have noted issues of conditioning long thought to be dependent on the materials from which the end pieces are constructed. This LDRD has been very helpful toward forming a less speculative model of the conditioning issues.

FY2016 Accomplishments

- The development of the test bed was completed, providing (1) gas and vacuum services for up to sixteen low level proportional counters, (2) a custom gas purged counter sprocket, (3) a multisegmented anticoincidence shield enveloping the sprocket, (4) a custom preamplifier shelf for reduction of microphonics, and (5) a heavy duty overhead electronics table. Such an arrangement was envisioned as being a flexible system for the likely modes of testing.

- The test bed features the capability to work with both NIM and VME standard instrumentation either separately or at the same time. This greatly reduces duplication costs.

- The modern digital signal processing module (VME) was installed in the test bed with the other electronics modules including one of our legacy DSP modules. This makes some important comparisons possible.

- The multisegmented anticoincidence shield was successfully installed and tuned with both the legacy counting equipment (NIM gear) and the NGTCS (VME gear).

- An initial set of working parameters has been successfully found for real pulses having noise that is typical of the low level proportional counters. The successful set of working parameters was then used as a starting point for working with the NGTCS hardware.

- The NGTCS has clearly demonstrated the ability the acquire spectra over the range of activities the system is likely to see.

- The summation of our recent acquired experience with the NGTCS and the legacy counting systems was put into a form that would be used as a guide to write the revised version of the data acquisition code. It also featured a recommended firmware modification for the DSP module in the NGTCS.

- The NGTCS circumvents a myriad of issues associated with having the signals from the counters summed before being analyzed by a single DSP. Qualitatively, in the NGTCS each channel has its own DSP and associated field programmable gate array, as a result there appears to be excellent separation among the channels. The result is reduced coupling and noise. Ultimately, with a more complete data acquisition code a number could be extracted to describe the difference quantitatively.

- Another benefit of the NGTCS over the legacy systems is the fact that we can have dissimilar signal sources in each channel of the modern DSP hardware. With the legacy systems a single FPGA and DSP served 16 similar channels. In the NGTCS, each counting channel has its own FPGA and DSP. This represents a significant cost savings over the lifetime of the NGTCS.

- The circular buffering associated with the NGTCS hardware appears to have had a beneficial effect on the counting. Whether this is due to the buffering or the association of one channel with one pulse stream remains to be determined. This cannot be done without the firmware and data acquisition code revision.

- The new low level counter design features end pieces whose construction greatly simplifies the process of preparing the counter for use. They feature improved seals, reduced axial travel, less and less parts. More time and testing is required to determine the optimal material. It would be very useful to run the NGTCS hardware during this process.

Future Directions

- The experimental counters will be run side by side with legacy counters in the NGTCS. We hope to gain a more complete understanding of both the long and short term issues associated with the detectors and the low level counting electronics. With this knowledge we seek to improve the low level tritium analyses on behalf of our customers.

- If such a thing exists and it is not cost prohibitive, we would like to select a more optimal material for constructing the end pieces.

- After the firmware and data acquisition code are modified the system should have the capabilities needed to continue the work of optimizing the working set of parameters for our application.

References

1. "Digital Acquisition Software for SRNL", SRNL-TR-2016-00260.

Acronyms

SRNL – Savannah River National Laboratory
DSP – Digital Signal Processor
FPGA – Field Programmable Gate Array
NGTCS – Next Generation Tritium Counting System
ULLCF – Ultra Low Level Counting Facility

Intellectual Property

N/A

Total Number of Post-Doctoral Researchers

N/A