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Pulse Detection Electronics Capstone Lab

*Abstract*—This experiment goes into the basics of setting up and using a Nuclear Instrumentation Module in order to perform a counting experiment and show the difference between multiple short runs up to a singular long run. Which is done by comparing the mean of each group of trials with the each trial’s count rate per minute mean. The results show that the shorter trial groups with the same total time as a long trial will have different means and error however the mean and error when applied to the count rate per minute of the trials will be relatively the same.

*Index Terms*—Counting Statistics, Pulse Detection, NIM, Radiation Detection Electronics

# INTRODUCTION

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UCLEAR radiations can be characterized with electric pulse electronics. Measuring incident radiation is essential for nuclear sciences and experiments. Radiation interactions with detectors produce information carries in the form of electrons or photons which can be analyzed by a Nuclear Instrumentation Module (NIM) “bin" [1]. The NIM bin enables spectroscopy of the incident radiation with various types of detectors.

The NIM bin contains various modules connected by coaxial cables. The NIM bin conforms to a standard in size and voltage requirements among other aspects which allows for a modular system of components. Components included for a general purpose counting detection system include a detector, detector bias, pre-amplifier, linear amplifier, oscilloscope, timing single channel analyzer, and counter [2]. Additional modules can be incorporated depending on the application of interest.

# Theory

The setup of a NIM detection system is critical for analysis of nuclear measurements. As stated, there are many components in a NIM bin detection system that require attention. A complete setup of a NIM bin detection system allows for the pulses created by a source to be counted and characterized for source energy. The explanation below focuses on the setup of a general nuclear detection counting system. An

The first component in the detection of nuclear radiation is a detector or pulser. Examples of detectors are Geiger-Mueller tubes, proportional counters, scintillation counters, and semiconductor devices, each having a different application in nuclear spectroscopy [2]. Each detector’s role is to convert the nuclear radiation into a detectable signal that can be analyzed. A detector bias is required depending on the detector type. The bias creates an electric field which is used to convert energy in to a measurable charge.

A pulser or pulse generator is used in the initial setup or calibration of a NIM bin [2]. The pulser can be used as a surrogate source to mimic a “tail pulse” of variable amplitude and polarization. The pulser or detector is connected to the pre-amplifier.

The pre-amplifier takes input from the detector or pulser as a source. The pre-amplifier is an intermediate amplification to increase the signal pulses for detection. Pre-amplifiers maximize the signal-to-noise ratio by cutting off the capacitance in a short time [2]. The pre-amplifier outputs a linear tail pulse that is the opposite polarity of the input from the source.

A linear amplifier functions to take the input from the preamplifier or detector and shape the tail pulse and amplitude. The standard NIM output is positive polarity with an amplitude of 0-10 V [2]. The linear amplifier has adjustable gain on the order of 10 to 1000. The settings on the amplifier offer a range of flexibility. The unipolar mode with long pulses is best suited for resolution, while the bipolar mode with short pulse input is best for high count rates [2]. An oscilloscope can be utilized anywhere in the chain of modules to inspect the pulses; however, the output of the amplifier is a good choice after the initial setup is complete.

The timing single channel analyzer (TSCA) converts the tail pulse into a logic pulse for counting. Discrimination can be applied to change what is counted as a pulse. Common modes for TSCAs are integral, normal, and window mode [3]. Integral mode operates based on a minimum threshold voltage from a lower level discriminator (LLD) [2]. Normal mode allows for the discrimination range to be between an upper level discriminator (ULD) and LLD set independently [3]. The window mode sets the LLD as a threshold voltage and has a window of voltage above that is included for conversion to a logic pulse [3]. A TSCA can also modulate the timing of the pulse. Characteristics of the incident radiation can be built from the various modes of a TSCA.

The counter converts the logic pulse created by the TSCA into a digital count. The discrete counts are built up for a pre-defined count time or count number, depending on the type of counter. The counter, under NIM standard, counts every logic pulse as a count. The output of the counts is of importance for nuclear detection and measurement. The energy bin constructed, type of detector, magnitude of the counts allows for the radiation to be characterized.

Binary counting statistics plays a fundamental role in nuclear experiments. Radioactive decay is characterized by the Poisson distribution [4]. Poisson distributions have properties based on the number of total counts if the probability of an individual occurrence is small and the sample size is relatively large. As cited by Leo, the mean (µ) of the counts (x) and the uncertainty (σ) with a given trial size (n) are related as follows.

(1)

From the mean count and uncertainty of the total count, the count rate per unit time can be created by dividing by the measurement time. It is important to create the uncertainty before dividing by the measurement time [4]. The count rate can be used to determine the contribution of the signal within the bounds defined by the TSCA.

# Experiment

The testing includes the setup of a NIM general purpose detection system. After the system is setup, a counting experiment is performed using a pulser as a source.

An ORTEC 480 pulser is utilized to drive the signal for the counting experiment. The pulser is set to 0.72 pulse height, negative polarity, 10X attenuation, and on the ON position. A terminator of 100 Ω is connected to the “DIRECT” line. The output parameters for the pulser and other outputs are summarized in Table I. The pulse output from the oscilloscope is shown in Figure 1.

FIGURE 1 maybe we should combine the 4 graphics on the same figure???

TABLE I

Units for Magnetic Properties

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Output Parameter | Pulser | Pre-Amplifier | Linear Amplifier | TSCA |
| Amplitude | 0.027 V | 0.124 V | 2.54 V | 6.08 V |
| Vmax | 0.005 V | 0.229 V | 2.57 V | 6.54 V |
| Vmin | -0.058 V | -0.049 V | -0.035 V | 0.16 V |
| Rise Time | 316 µs | 10.1 ns | 2.4 µs | 39 ns |
| Fall Time | 23 ns | 58 µs | 4.1 µs | 32 ns |

The attenuated pulser output is connected by a coaxial cable to the test input on an ORTEC 142pc pre-amplifier. The test mode is used for pulsers. The preamplifier requires its own power source, independent from the NIM bin. The amplifier output from the “ENERGY” terminal is shown in Figure 2. The signal is inverted from the pulser and larger in magnitude.

FIGURE 2

The “ENERGY” output of the pre-amplifier is connected to the input on an ORTEC 572 Linear Amplifier. The course gain and fine gain are set to 20 and 0.624. The sampling time is 2 µs with BLR mode on and the delay switch on. The polarization is set to positive, which maintains the positive polarity from the pre-amplifer. The unipolar signal from the linear amplifier is shown in Figure 3.

Figure 3

The “UNI” output is connected to the DC input of an ORTEC 551 TSCA. The ULD is set to 5.1 V, and the LLD is set to 1.25 volts. The mode is set to NOR, which allows for independent adjustment of the levels of the LLD and ULD. The timing is set to 0.1 µs. The signal from the TSCA is shown in Figure 4. The output is a logic square pulse, which is optimal for the counter input.

FIGure 4

The “POS” output of the TSCA is connected to the “POS” input of an ORTEC 996 Counter. The completed setup off the general purpose counting system is shown in Figure 5. The counter has adjustable count times which are used for the counting portion of the experiment which includes 5 1-min counts, 2 2.5-min counts, 3 100s counts, and 1 5-min count. The total counts during each trial are recorded and analyzed.

Figure 5

TABLE 2

Results

|  |  |  |
| --- | --- | --- |
| Time Ran | Preset | Counts |
| 1 Min | 10x101 | 3599 |
|  |  | 3598 |
|  |  | 3598 |
|  |  | 3598 |
|  |  | 3598 |
| 2.5 Min | 25x101 | 8995 |
|  |  | 8997 |
| 100 Sec | 10x103 | 5998 |
|  |  | 5999 |
|  |  | 5999 |
| 5 Min | 05x102 | 17992 |

# Results and Discussion

Once the data from the experiment had been collected two different ways of analysis methods were performed for the purpose of showing how multiple short runs can be equivalent to single long run. To do this the mean and error is calculated as standard and recorded as seen in Table 3. Then the mean is changed into the Count Rate per Minute and the error is recalculated by dividing it by the time that had passed and recorded in Table 4. Finally the differences, or lack thereof, can be clearly observed.

TABLE 3

Calculations

|  |  |  |
| --- | --- | --- |
| Time Ran | Mean | Error |
| 1 Min | 3598.2 | 26.826 |
| 2.5 Min | 8996 | 67.067 |
| 100 Sec | 5998.67 | 44.716 |
| 5 Min | 17992 | 134.134 |

TABLE 4

Calculations with CR/M

|  |  |  |
| --- | --- | --- |
| Time Ran | Mean | Error |
| 1 Min | 3598.2 | 26.826 |
| 2.5 Min | 3598.4 | 26.827 |
| 100 Sec | 3599.2 | 26.83 |
| 5 Min | 3598.4 | 26.827 |

From here it is easy to see that for certain experiments it is possible to break a single experiment into multiple smaller ones whose overall time is equivalent. This is advantageous for several reasons the first being that the experiment can be potentially done at different times. Secondly if the experiment can only be done in short bursts it is possible to determine what the experiment would result in if it was allowed to run for a long time.

# References

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