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Pulse Detection Electronics Capstone Lab

*Abstract*—These in

*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 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

If you are using *Word,* use either the Microsoft Equation Editor or the *MathType* add-on (http://www.mathtype.com) for equations in your paper (Insert | Object | Create New | Microsoft Equation *or* MathType Equation). “Float over text” should *not* be selected.

Be sure that the symbols in your equation have been defined before the equation appears or immediately following. Italicize symbols (*T* might refer to temperature, but T is the unit tesla). Refer to “(1),” not “Eq. (1)” or “equation (1),” except at the beginning of a sentence: “Equation (1) is ... .”

# Results and Discussion

The SI unit for magnetic field strength *H* is A/m. However, if you wish to use units of T, either refer to magnetic flux density *B* or magnetic field strength symbolized as µ0*H*. Use the center dot to separate compound units, e.g., “A·m2.”

# References

TABLE I

Units for Magnetic Properties

|  |  |  |
| --- | --- | --- |
| Symbol | Quantity | Conversion from Gaussian and  CGS EMU to SI a |
| Φ | magnetic flux | 1 Mx → 10−8 Wb = 10−8 V·s |
| *B* | magnetic flux density,  magnetic induction | 1 G → 10−4 T = 10−4 Wb/m2 |
| *H* | magnetic field strength | 1 Oe → 103/(4π) A/m |
| *m* | magnetic moment | 1 erg/G = 1 emu  → 10−3 A·m2 = 10−3 J/T |
| *M* | magnetization | 1 erg/(G·cm3) = 1 emu/cm3  → 103 A/m |
| 4π*M* | magnetization | 1 G → 103/(4π) A/m |
| σ | specific magnetization | 1 erg/(G·g) = 1 emu/g → 1 A·m2/kg |
| *j* | magnetic dipole  moment | 1 erg/G = 1 emu  → 4π × 10−10 Wb·m |
| *J* | magnetic polarization | 1 erg/(G·cm3) = 1 emu/cm3  → 4π × 10−4 T |
| χ*,* κ | susceptibility | 1 → 4π |
| χρ | mass susceptibility | 1 cm3/g → 4π × 10−3 m3/kg |
| μ | permeability | 1 → 4π × 10−7 H/m  = 4π × 10−7 Wb/(A·m) |
| μr | relative permeability | μ → μr |
| *w, W* | energy density | 1 erg/cm3 → 10−1 J/m3 |
| *N, D* | demagnetizing factor | 1 → 1/(4π) |

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

aGaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

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| [1] | "Lab Manual, Pulse Detection Electronics (Weeks 1 & 2)," NENG 605, AFIT, Winter 2018. |
| [2] | G. F. Knoll, Radiation Detection and Measurement, Ann Arbor, Michigan: Wiley, 2010. |
| [3] | ORTEC, "Model 551 Timing Single-Channel Analyzer Operating and Service Manual," Advanced Measurement Technology, Inc. , 2002. |
| [4] | W. R. Leo, Techniques for Nuclear and Particle Physics Experiments, New York: Springer-Verlag, 1994. |



Fig. 1. Magnetization as a function of applied field. Note that “Fig.” is abbreviated. There is a period after the figure number, followed by two spaces. It is good practice to explain the significance of the figure in the caption.

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