

# A Digital Method for the Discrimination of Neutrons and $\gamma$ Rays With Organic Scintillation Detectors Using Frequency Gradient Analysis

Charles C. Lee, Michael D. Jones, Xiaoting Ma, and Richard D. Applegate

**Abstract**—A digital method for the discrimination of neutrons and  $\gamma$  rays using organic scintillation detectors is described by using frequency gradient analysis (FGA) based on the Fourier transform. Since the discrimination process and the photomultiplier tube (PMT) signals used are often very noisy, some pulse-shape discrimination methods are investigated for these systems (e.g., the charge comparison (CC) method or pulse gradient analysis (PGA) using two channels). Features of the signal gradient spectra are the percentage of leading structure, the 50% rise time, the performance of the rise time method and the FGA method have been studied and compared with theoretical results and have verified by Monte Carlo (MC) and computer simulations. Features extracted by the FGA method related to rising structure in the spectrum are good measures of the photomultiplier tube (PMT) and can be used for discrimination between and  $\gamma$  rays using a digital multichannel analyzer (DMA) which consists of an internal multichannel analyzer (MCA). It is shown that the FGA method results in an increased figure of merit (FOM) when compared to a multichannel in the area of counting between neutrons and  $\gamma$  rays using the PMT method. The purpose of the implementation is to make multichannel systems to provide real-time discrimination for detection instruments.

**Index Terms**—Digital discrimination, frequency gradient analysis, neutron, organic scintillation, pulse gradient analysis, rise of signal.

## I. INTRODUCTION

ORGANIC scintillation detectors have often been used for the detection and spectroscopy of  $\gamma$ -rays, measurement of neutrons. For the most majority of liquid organic scintillators, the composite pulse wave consists of two superimposed shapes—the fast and slow components of the scintillation. Therefore the shape of light that appears in the slow component often depends on the nature of the exciting particle, one can use this dependence to differentiate different kinds of radiation. Liquid organic scintillators including alcohols and members of aromatic and liquid scintillators, are particularly good examples of this phenomenon that is explained via pulse shape discrimination (PSD). This is because of the large difference in the slow component followed by different scintillators in these media. When organic scintillators are used in neutron detectors, PSD is an essential requirement because all neutron fields contain both

an unwanted  $\gamma$ -ray component arising as a result of scattering reactions of the neutrons with materials in the environment, and no direct separation of the primary reaction producing the neutron field [1].

A number of techniques for PSD have been investigated with varying degrees of success. The most popular of these are the charge comparison method [2] and the rise timing method [3]. Both of these methods were originally implemented in analog electronics, often in dedicated instrumentation modules or service instrument modules (SIMs). More recently, both of these methods have been been implemented in the digital domain as digital electronic systems have become available with their fast rise-time and fast analysis to make this possible. These methods have become the industrial standards for neutron systems with other new proposed discrimination methods, such as the correlation method [4] and the cosine timing method [5].

In recent years, artificial neural networks (ANN) and fuzzy systems [6] have emerged as system technologies, with several applications across many fields. They are particularly effective in pattern recognition tasks, and in this sense, ANN and FS can be used to classify neutrons and  $\gamma$ -ray events from the measurements performed by organic liquid scintillation detectors. In particular, Li [7] and Li et al. [8] used a fuzzy logic approach to neural networks to process the shape of light pulse in an organic liquid scintillation, while D'Astous [9] proposed an approach based on fuzzy logic for pulse-shape discrimination in a liquid-based scintillation detector.

In order to take advantage of capabilities offered by fast digital electronics, Bortolotto et al. [10] presented a discrimination system that is computationally simple, referred to as pulse gradient analysis (PGA). This technique provides real-time digital characterization of measurements where neutrons and  $\gamma$ -rays coexist. The performance of the PGA method has been compared against a digital implementation of the conventional charge comparison method which demonstrated the PGA method provides an improvement in discrimination ability. Very recently, a dedicated portable neutron/analog device developed that provides real-time discrimination of mixed fields that is based on the PGA algorithm deployed on Kilobit Space 177 field-programmable gate array [11].

One of the many pulse-shape discrimination methods are two-channel features of the signal, e.g., the implementation of charge comparison method generally refers to the integration of the pulse over two different intervals and that of PGA method is based on the comparison of the relative heights of complex in the trailing edge of the pulse. Since the scintillation process

Manuscript received May 10, 1984; revised November 13, 1984; accepted November 13, 1984. This work was supported by the U.S. Army Research Office-Durham, Durham, NC, under the sponsorship and technical assistance of the Army Research Office-Durham, Durham, NC.

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proceedings will feature peer reviewed papers that illustrate research results projects surveys and industrial experiences that describe significant advances in the diverse areas of computer networks communications      **Advanced Intelligent Computing Technology and Applications** De-Shuang Huang,Wei Chen,Yijie Pan,2024-08-01 This 13 volume set LNCS 14862 14874 constitutes in conjunction with the 6 volume set LNAI 14875 14880 and the two volume set LNBI 14881 14882 the refereed proceedings of the 20th International Conference on Intelligent Computing ICIC 2024 held in Tianjin China during August 5 8 2024 The total of 863 regular papers were carefully reviewed and selected from 2189 submissions This year the conference concentrated mainly on the theories and methodologies as well as the emerging applications of intelligent computing Its aim was to unify the picture of contemporary intelligent computing techniques as an integral concept that highlights the trends in advanced computational intelligence and bridges theoretical research with applications Therefore the theme for this conference was Advanced Intelligent Computing Technology and Applications Papers that focused on this theme were solicited addressing theories methodologies and applications in science and technology

*Digital Forensics and Watermarking* Yun Qing Shi,Hyoung Joong Kim,Fernando Perez-Gonzalez,Feng Liu,2017-02-14 This book constitutes the revised post conference proceedings of the 15th International Workshop on Digital Forensics and Watermarking IWDW 2016 held in Beijing China in September 2016 The 45 papers presented in this volume were carefully reviewed and selected from 70 submissions The contributions are organized in topical sections on digital forensics visual cryptography reversible data hiding and steganography and steganalysis

**High Performance Architecture and Grid Computing** Archana Mantri,Suman Nandi,Gaurav Kumar,Sandeep Kumar,2011-07-05 This book constitutes the refereeds proceedings of the International Conference on High Performance Architecture and Grid Computing HPAGC 2011 held in Chandigarh India in July 2011 The 87 revised full papers presented were carefully reviewed and selected from 240 submissions The papers are organized in topical sections on grid and cloud computing high performance architecture information management and network security

Neural Information Processing Mufti Mahmud,Maryam Doborjeh,Kevin Wong,Andrew Chi Sing Leung,Zohreh Doborjeh,M. Tanveer,2025-07-21 The eleven volume set LNCS 15286 15296 constitutes the refereed proceedings of the 31st International Conference on Neural Information Processing ICONIP 2024 held in Auckland New Zealand in December 2024 The 318 regular papers presented in the proceedings set were carefully reviewed and selected from 1301 submissions They focus on four main areas namely theory and algorithms cognitive neurosciences human centered computing and applications

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techniques machine vision and 3D reconstruction image video big data analysis and understanding computer graphics visualization and visual analysis virtual reality and human computer interaction and applications of image and graphics

**Advanced Hybrid Information Processing** Shuai Liu,Gelan Yang,2019-05-12 This book constitutes the refereed proceedings of the Second EAI International Conference on Advanced Hybrid Information Processing ADHIP 2018 held in Yiyang China in October 2018 The 71 papers presented were selected from 228 submissions and focus on hybrid big data processing Since information processing has acted as an important research domain in science and technology today it is the right time to develop deeper and wider use of hybrid information processing especially information processing for big data There are more remaining issues waiting for solving such as classification and systemization of big data objective tracking and behavior understanding in big multimedia data encoding and compression of big data *System Innovation for a Global Economy* Artde Donald Kin-Tak Lam,Stephen D. Prior,Siu-Tsen Shen,Sheng-Joue Young,Liang-Wen Ji,2025-10-10 System Innovation for a Global Economy contains the contribution to the 2025 International Conference on Applied System Innovation ICASI 2025 Tokyo Japan April 22 25 2025 Of the more than 500 submitted papers from 14 different countries after review approximately a quarter was accepted for publication The book aims to provide an integrated communication platform for researchers from a wide range of topics including information technology communication science applied mathematics computer science advanced material science and engineering System Innovation for a Global Economy enhances interdisciplinary collaborations between science and engineering technologists and is aimed at academics and technologists interested in the above mentioned areas *Frontiers in Cyber Security* Biwen Chen,Xinwen Fu,Min Huang,2024-12-26 This two volume set CCIS 2315 and CCIS 2316 constitutes the refereed proceedings of the 7th International Conference on Frontiers in Cyber Security FCS 2024 held in Chongqing China during July 26 28 2024 The 47 full papers presented in these two volumes were carefully reviewed and selected from 121 submissions The papers are organized in the following topical sections Part I Machine Learning and Differential Privacy Federated Learning Privacy Preserving Services Blockchain and Distributed System Public Key Cryptography Multi Party Computation Part II Multi Party Computation Smart Grid Authentication and Deduplication *Multimedia Forensics and Security* Li, Chang-Tsun,2008-07-31 As information technology is rapidly progressing an enormous amount of media can be easily exchanged through Internet and other communication networks Increasing amounts of digital image video and music have created numerous information security issues and is now taken as one of the top research and development agendas for researchers organizations and governments worldwide Multimedia Forensics and Security provides an in depth treatment of advancements in the emerging field of multimedia forensics and security by tackling challenging issues such as digital watermarking for copyright protection digital fingerprinting for transaction tracking and digital camera source identification

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