Development of FPGA-Based Nuclear Electronics using NI MyRIO Hardware for Small-Scale Radiation Detector Systems

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Abstract– This study presents advancements in coincidence electronics and a Pulse Height Analyzer (PHA) utilizing commercial FPGA-based (Field-Programmable Gate Array) hardware for radiation scintillation detectors. The hardware, based on a cost-effective NI myRIO device, integrates a Field-Programmable Gate Array (FPGA), ARM Cortex-A9 processor, analog input (AI), digital input and output (DIO), and USB/wireless connectivity with a host computer. LabVIEW codes, developed on the LabVIEW™ platform, are implemented in NI myRIO hardware for seamless integration and computer interface. The FPGA-based coincidence electronics performance is assessed through an experimental setup for the gamma-gamma angular distribution of a Na-22 radioisotope source. Similarly, the FPGA-based PHA undergoes testing with a NaI(Tl) detector, with a subsequent comparison of energy resolution against a commercial EASY-MCA 2K from AMETEK Inc.

I. INTRODUCTION

Coincidence electronics and pulse height analyzers stand as pivotal techniques in radiation detection systems [1]. The development of FPGA-based nuclear electronics has garnered attention due to their programmability, simplicity, testability, compact size, and low power consumption. This technology is increasingly favored worldwide for nuclear electronic systems over traditional analog counterparts. Building upon our previous works [2],[3], where FPGA technology was applied to cosmic ray angular electronic system and gamma energy detectors.

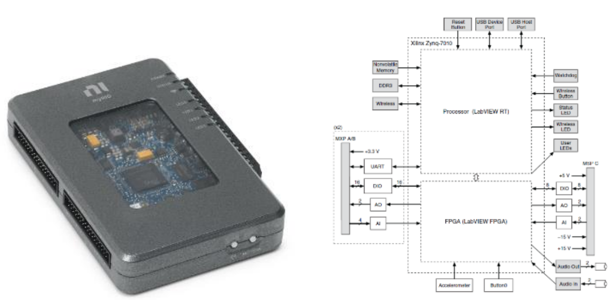


Figure 1. Hardware illustration of the NI MyRIO device, featuring an FPGA, ARM Cortex-A9 processor, analog input (AI), and digital input and output (DIO) [4].

This work focuses on developing FPGA-based nuclear electronics using a compact NI MyRIO hardware [4], Figure 1. The embedded code in NI MyRIO hardware and computer interface is realized using the LabVIEW software platform [5].

This paper details two key developments: the FPGA-based Coincidence electronics for the gamma-gamma angular distribution system (Section II) and the FPGA-based PHA for the gamma energy detector of NaI(Tl) (Section III).

II. GAMMA-GAMMA ANGULAR DISTRIBUTION

II.1. FPGA-based Coincidence electronic

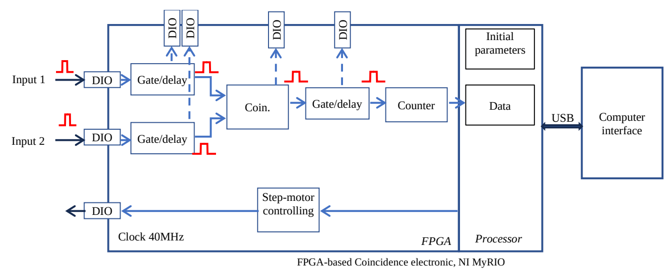


Figure 2. Schematic diagram of FPGA-based coincidence electronic.

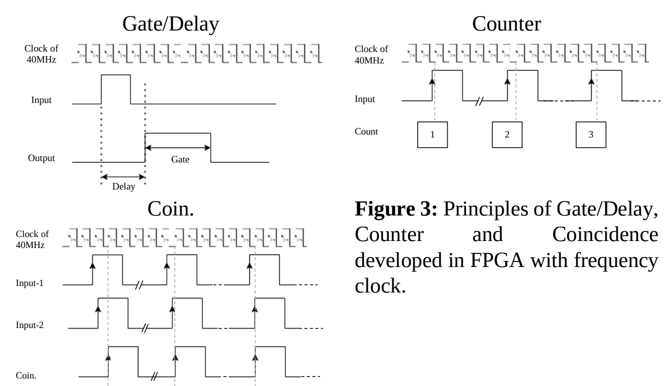


Figure 3: Principles of Gate/Delay, Counter and Coincidence developed in FPGA with frequency clock.

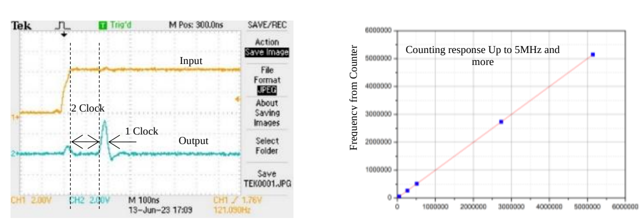


Figure 4. Timing (left) and counting (right) response of the FPGA-based coincidence electronics using a standard pulser. Note: 1 clock = 25nsec.

II.2. Gamma-gamma angular distribution system

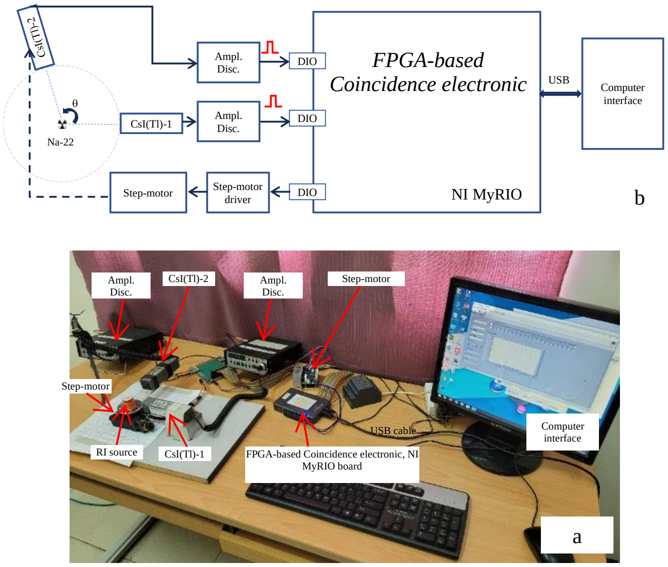


Figure 5: Schematic arrangement (a) and experimental site (b) of the gamma-gamma angular distribution system.

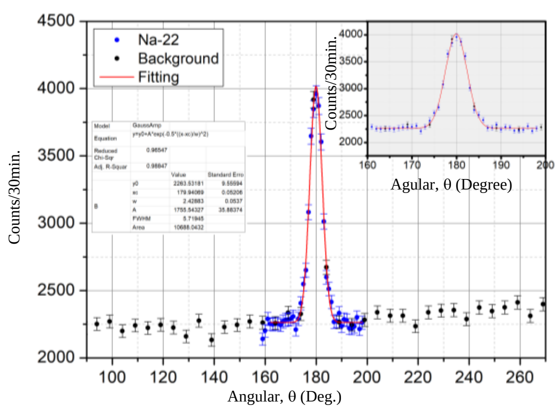
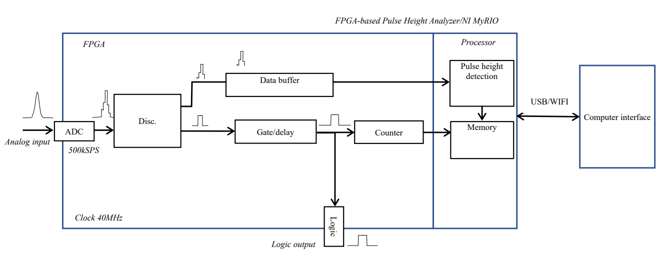


Figure 6: Angular distribution of gamma-gamma emissions from Na-22 source. A annihilation peak is clearly observed with back-to-back.

III. FPGA-BASED PULSE HEIGHT ANALAYER

III.1. FPGA-based PHA electronic



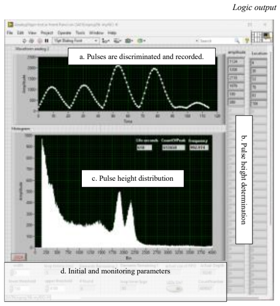


Figure 7: Schematic diagram of FPGA-based PHA electronics.

III.2. Gamma energy spectroscopy detector of NaI(Tl)

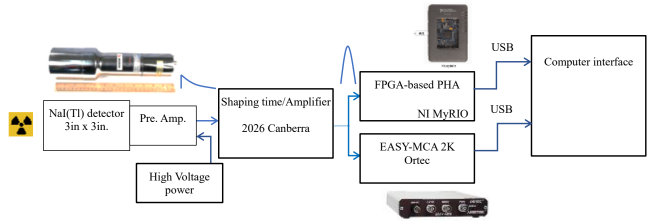


Figure 8: Gamma energy detector of NaI(Tl) utilizing FPGA-based PHA (this work) and EASY-MCA 2K from AMETEK Inc.

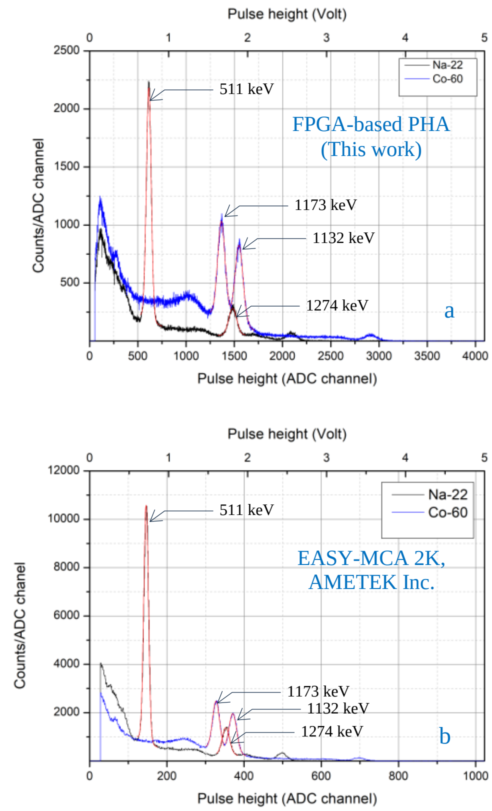


Figure 9: Gamma energy spectra of NaI(Tl) detector for Na-22 and Co-60 using FPGA-based PHA (this work) (a) and EASY-MCA 2K, AMETEK Inc. (b).

TABLE I. COMPARISON OF GAMMA ENERGY RESOLUTION FOR NAI(TL) DETECTORS USING FPGA-BASED PHA (THIS WORK) AND COMMERCIAL EASY-MCA 2K FROM AMETEK INC.

RI sources	***Energy (keV)***	***Energy resolution (%)***	
		FPGA-based PHA (This work)	*EASY-MCA 2K, AMETEK Inc.*
Na-22	511	10.4 ± 0.1	10.4 ± 0.1
	1274	7,0 ± 0.1	6.8 ± 0.1
Co-60	1173	6.9 ± 0.1	7.1 ± 0.1
	1332	6.6 ± 0.1	6.7 ± 0.1

IV. CONCLUSIONS

The development of FPGA-based Coincidence electronic facilitates gamma-gamma angular distribution experiments, revealing a distinct annihilation peak from the Na-22 source. The system's automation potential, incorporating angular rotation via a step motor, coincidence counting, and spectrum saving, is demonstrated. Additionally, the FPGA-based PHA for the NaI(Tl) detector exhibits commendable performance in comparison to the commercial EASY-MCA 2K from AMETEK Inc.

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