Developing an Arduino-Based Peak Detector Circuit for Gamma Spectrum Measurement

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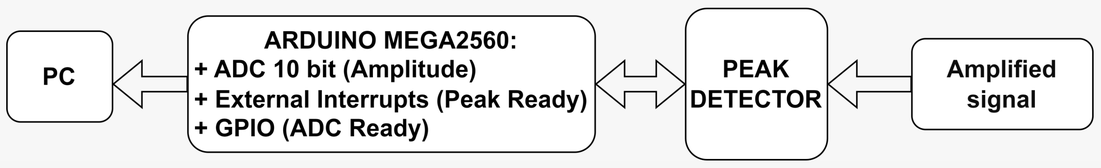
Abstract

In this article, we describe the development of an electronic circuit for measuring the pulse amplitude of scintillation detectors using an Arduino Mega 2560 pro (Embed). The amplified analog signals are fed into a peak detector circuit [1]. In addition to this circuit, we have incorporated components such as op-amp comparators, flip-flops, and analog switches to ensure accurate signal sampling through the Arduino. To test the system's performance, we used standard pulses with amplitudes ranging from 200mV to 3200mV generated by the RIGOL DG4062 pulse generator. The survey results show a full-scale non-linearity of less than 0.5%. Furthermore, we measured the energy spectrum of gamma rays emitted by various isotopes such as ^{133}Ba, ^{22}Na, ^{137}Cs, and ^{60}Co using a NaI(Tl) detector (Model 44-10) and counter (Model 4612) manufactured by Ludlum Measurements, Inc , and our system. The results indicate that the Full Width at Half Maximum (FWHM%) at 81KeV is 15.46%, at 356KeV is 9.90%, at 511KeV is 8.57%, at 662KeV is 8.36%, at 1173KeV is 5.24%, and at 1332KeV is 6.15%. This is a simple and cost-effective design that can be used to construct gamma-ray spectroscopy devices for educational purposes.

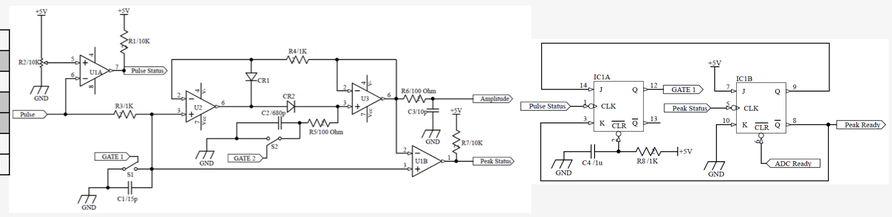
Introductions

Research on the energy levels of gamma rays holds paramount significance in nuclear physics research and educational endeavors. Nevertheless, the procurement of specialized equipment for gamma energy spectrum measurements often incurs considerable expenses. Presently, readily available integrated circuits with moderate precision and cost-effectiveness, such as the microcontrollers on the Arduino board, are widely accessible. Arduino, with its open-source community and versatile design, has emerged as a preferred platform for a plethora of applications ranging from elementary to intricate. Several studies have employed Arduino for specific gamma spectrum measurements [2]. The objective of our paper is to propose a circuit design for quantifying pulse amplitude from scintillation detectors used for gamma rays, such as NaI(Tl) detectors. This design involves augmenting certain components into a peak detector circuit and integrating it with an Arduino Mega2560 Pro (Embed), thereby facilitating the determination of gamma ray energy spectra.

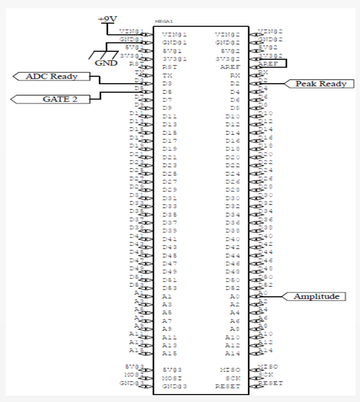
Materials and methods: Operational Diagram & Schematic Diagram

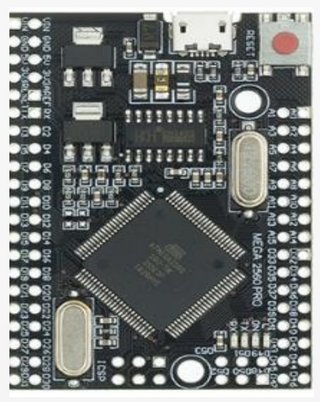


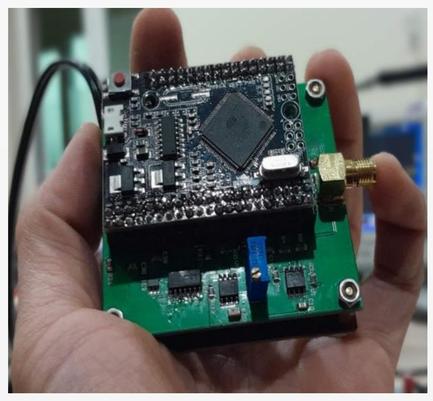
Components	Name
U1	TLC372
U2	AD847
U3	AD843
S1, S2	TMUX1101
CR1, CR2	1N4148
IC1	CD74HC73



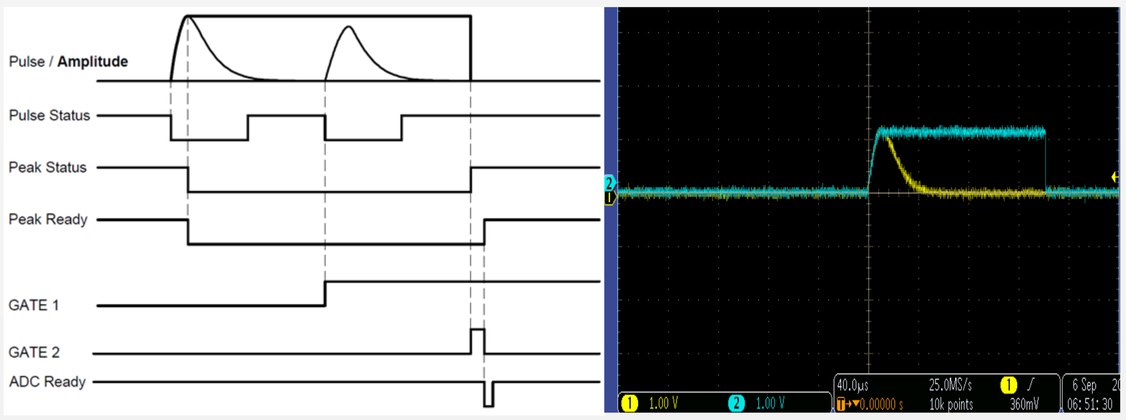
Materials and methods: Arduino Mega 2560 Pro (Embed)



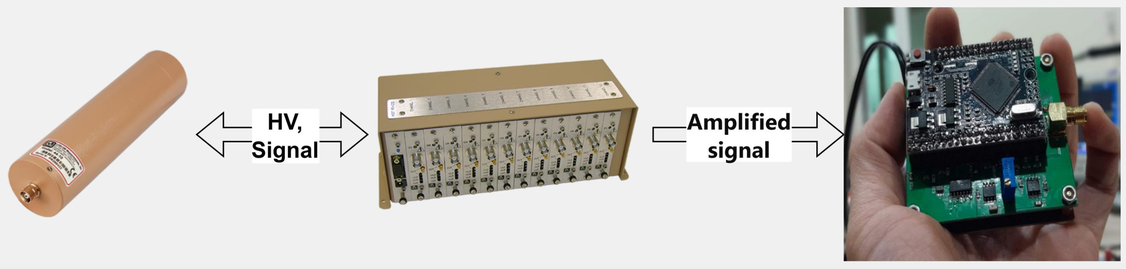




Materials and methods: Timing Diagram

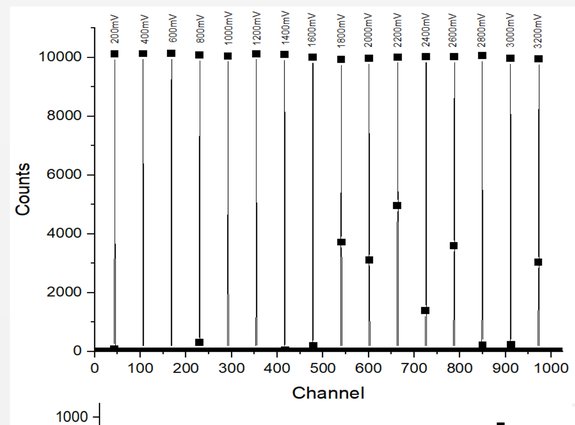


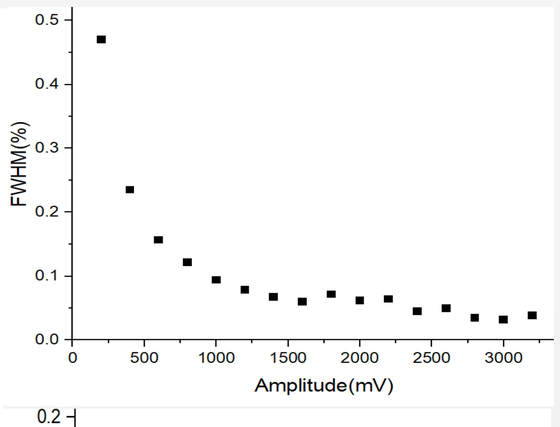
Energy Calibration Diagram And Results

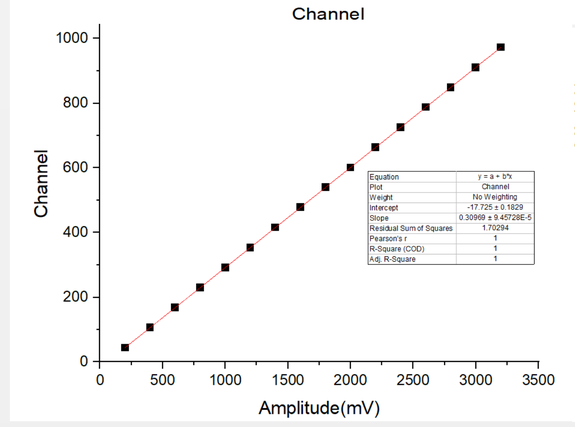


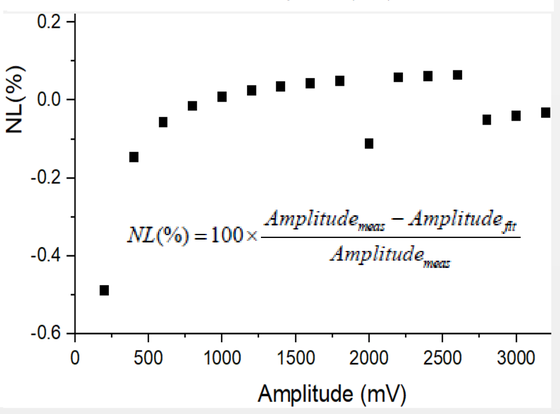
DETECTOR M44-10 | **COUNTER M4612** | **Arduino-based peak detector**

Materials and methods: Results Non-Linearity and Electronic Noise

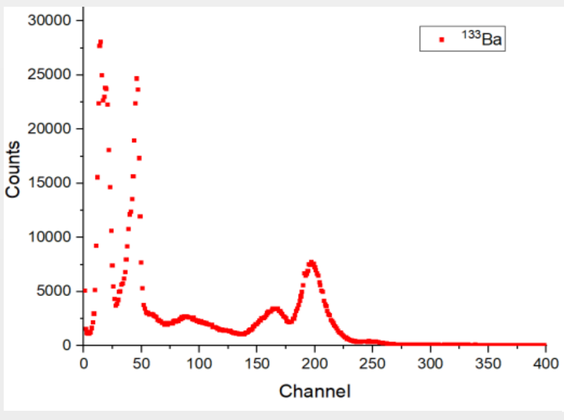


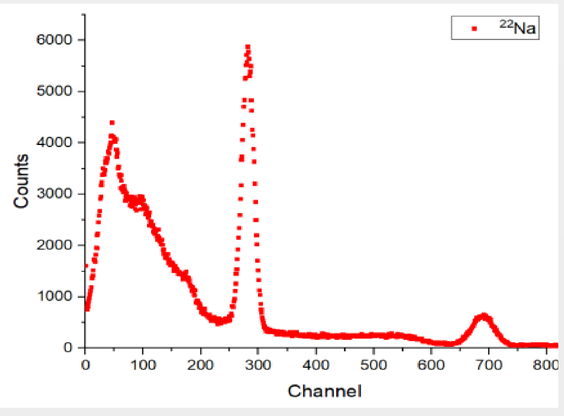


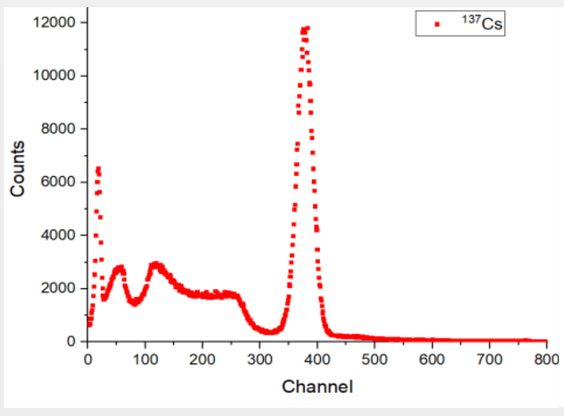


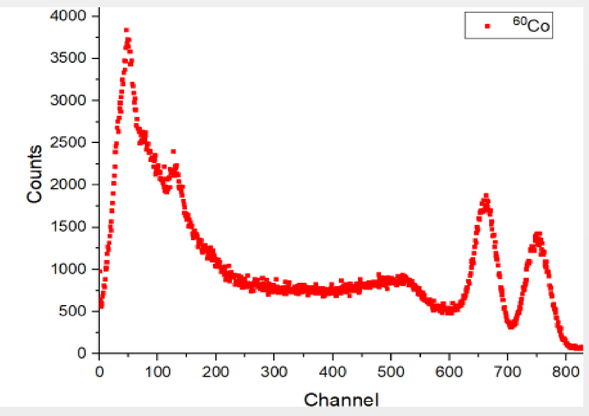


Results Energy Calibration









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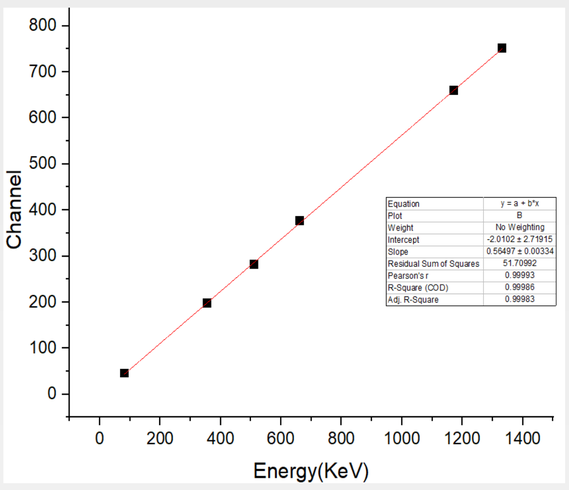

Isotopes	Energy (KeV)	FWHM(%)	Error (%)	NL(%)
^{133}Ba	81	15.46	6.87	4.07
	356	9.90	0.91	-0.83
^{22}Na	511	8.57	0.69	-1.66
^{137}Cs	662	8.36	0.59	1.28
^{60}Co	1172	5.24	2.88	-0.09
	1332	6.15	1.61	0.04

Discussion

Our experiments have affirmed the system's stability and reliability, demonstrating consistent electronic noise levels below 0.5% FWHM at 200mV amplitude, and minimal nonlinearity, remaining below 0.5% at the same voltage. Additionally, our comprehensive surveys of gamma energy spectra across various radioisotopes underscore the system's versatility, boasting impressive accuracy across a wide range of energies: 81KeV (15.46%), 356KeV (9.90%), 511KeV (8.57%), 662KeV (8.36%), 1173KeV (5.24%), and 1332KeV (6.15%). These results underscore the cost-effectiveness and ease of integration of the system, while also emphasizing its compact design, rendering it a viable solution across diverse applications. Notably, its suitability for educational contexts and its potential for implementation in low-cost systems further enhance its utility.

Conclusion

We have successfully developed a peak detection circuit based on the Arduino Mega 2560 for gamma spectroscopy. The use of Arduino for gamma spectroscopy systems has been demonstrated as an ideal choice due to its low cost, ease of deployment, and accessibility to a wide range of users.

Acknowledgments

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References

[1]. Lew Counts and Mark Murphy, Peak Detector Circuit Captures 200-ns Pulses. With speed and low droop-other performance enhancement feasible Key is FET-input op amp fabricated on complementary-bipolar process, JUN 1990 VOL 24, Analog Dialogue 24-2 1990.
[2]. C. M. Lavelle, Gamma ray spectroscopy with Arduino UNO, American Journal of Physics, Volume 86, Issue 5, p.384-394, May 2018, DOI:10.1119/1.5026595.