Semiconductor Detectors

J.R. Powers-Luhn

April 27, 2017

1 Abstract

Here students will tell the reader what was done, why it was done, the important results, and what the significance is. This section is an overview of the entire write up and should be concise and to the point. No figures go into this section but final values do (including uncertainty) and conclusions drawn from these results. This section should be only 250-500 words.

2 Introduction

This section should cover the basic concepts of what the purpose of the laboratory is. This, in most cases, will require research on the part of the student to figure out what underlying concepts are associated with the assignment. This section is also the theory section. Any references used must be cited and plagiarism will result in automatic F for the assignment. Safe Assign will check all sources, within UTK and online, for text matching any source. The purpose of this section is to allow students to demonstrate an understanding of the basic concepts of the course and the topics covered within the laboratory assignment. This section should be between 3-7 pages.

3 Experimental

3.1 MCA Linearity

In order to determine the linearity response of the ORTEC 927 ASPEC MCA, a model BNC BL-2 voltage pulse generator was connected through an ORTEC 572A amplifier to the MCA while the output of the pulse generator was also monitored via an GW INSTEK model GDS-3254 oscilloscope, as indicated in figure **??**. The output of the MCA was recorded in the Maestro software for several voltage settings, and the channels corresponding to each peak recorded.

3.2 MCA Dead Time

In order to determine the dead time of the MCA, the pulse generator was then set to produce a double pulse with a 3 μs rise time and a 10 μs fall time. Amplifier shaping time was set to 0.5 μs with an amplitude of 5.44 V. The MCA was set to conduct a continuous collection with a 12 bit conversion gain. The spacing between the pulse was adjusted and the threshold at which the MCA was able to distinguish between the pulses (the point at which two peaks appeared on the spectrum) recorded.

3.3 HPGe Evaluation

The MCA was then connected to an HPGe/Preamplifier/Amplifier chain as indicated in figure **??**. The amplifier shaping time was set to 10 μs with a gain setting of 10 and unipolar output. After a 10 min background was collected, an assortment of sealed sources were placed at a distance of approximately 10 cm from the detector face. Information regarding the sources is presented in table 1. Spectra for these sources were collected in the highest-available number of channels (14 bits) in order to take advantage of the high resolution of the HPGe detector. Sources were counted for 150 s in order to obtain sufficient counts to obtain reasonable statistics.

Table 1: Sources for HPGe Evaluation

Source	Date	Activity
Na-22	April 2015	1 μCi
Cs-137	April 2015	10 μCi
Co-60	May 2012	1 μCi
Mn-54	February 2012	10 μCi
Cd-109	May 2015	1 μCi
Ba-133	February 2012	1 μCi
Co-57	May 2015	1 μCi

3.4 HPGe Geometric variation

A 1 μCi Cs-137 source dated February 2012 was used to determine the response of the HPGe detector to sources at various ranges. The source was placed in a holder above the detector face. A 150 s spectrum was recorded on contact and at heights of (2.6 ± 0.3) cm, (6.2 ± 0.3) cm, (9.4 ± 0.3) cm, (11.5 ± 0.3) cm, and (14.7 ± 0.3) cm.

3.5 CZT Evaluation

An effort was made to objectively compare the HPGe detector to another type of detector, namely a Cadmium Zinc Telluride (CZT) detector. This data collection was performed by the course instructors, so precise settings for the electronics chain were not available at the time of this report. The information that was available for this experiment is recorded in table 2.

Table 2: Sources and count time for CZT evaluation

Source	Count time (s)
Na-22	300
Co-57	300
Co-60	600
Cd-109	300
Ba-133	300
Cs-137	120

3.6 Sodium Iodide Evaluation

4 Results

4.1 MCA performance

4.2 HPGe Resolution and efficiency

The spectra from the assorted sources were analyzed using Python and the PeakFinder library in order to determine a relationship between channel number and energy. The detected peaks were correlated to known gamma emission spectra for these sources and a linear fit was performed on this data. A plot of the data and the linear fit can be seen in figure **??**. Based on the $R^2 > 0.9999$ value, it was determined that further analysis could be conducted in terms of energy vice channel number, and the spectra were converted accordingly.

The spectrum for the Na-22 source showed significant photopeaks, as expected (see figure **??**). The principle gamma emission from the Na-22 source is visible at E=(1274.0 ± 0.1) keV, (see equation 1). The largest peak in this spectrum corresponded to the annhilation of the positrons from the source, corresponding to an energy of 511 keV. These gamma rays produced secondary scattering events via the process of Compton Scattering. This process produced a continuous spectrum (due to the three-body nature of the products of Compton Scattering event), the maximum energy (see equation 2) produces an observable drop in the energy which corresponds to the maximum energy of the scattered electrom from these events. This is visible as a ”Compton Edge”.

This feature appears to one degree or another in most of the spectra recorded for this report.

$$E_\gamma = m_e \times c^2 = 511\,\mathrm{keV} \tag{1}$$

$$E_s^{Max} = E_\gamma \left(1 - \frac{1}{1 + \frac{2E_\gamma}{m_e c^2}}\right) \tag{2}$$

The spectrum for the Mn-54 source (see figure **??**) showed a single peak at 835 keV and no other visible features. This corresponds to its electron capture decay, which occurs with a branching frequency of greater than 0.9999 .

Two isotopes of Cobalt were examined, Co-57 and Co-60. Co-57 decays via several modes, only three of which have significant branching fractions (>1%). The lowest energy of these, an electron capture at 14.4 keV was low enough energy that it was not visible in the background-corrected spectrum (due to the prevalence of X-rays in the low-energy region below approximately 20 keV). The remaining two peaks are closely spaced at 122 keV and 136 keV, making them a good mechanism to evaluate the resolution of a detector. As expected, the two peaks were distinct on the plotted spectrum, as can be seen in figure **??**. The distinct peaks also provide the opportunity

In order to determine the detector efficiency for each of the photopeaks from the sources, the spectral data representing each of the peaks were segregated out and treated separately for this portion.

5 Conclusion

This section is a final overview of the results and their significance. This should be a summary of section 4, the results section, with an overarching view of the results. This section should be no more than one page.

The ORTEC 927 ASPEC MCA was determined to perform within the ranges required for spectral analysis, with sufficient resolution and linear response at a variety of input voltages. The performance of an HPGe detector was analyzed for a variety of well-characterized sources. Its resolution

Table 3: Efficiency of HPGe Detector

Source	Energy ($\pm$ 0.1 keV)	FWHM (keV)	Photopeak (cps $\times$ keV)	Total (cps $\times$ keV)	Photopeak efficiency
Na-22	511	2.83	25.4	2339	0.011
	1274	2.75	4.48	2339	0.0019
Mn-54	835	1.73	0.861	82.5	0.010
Co-57	122	1.05	15.7	413.2	0.038
	136	1.06	1.90	413.2	0.0046
Co-60	1173	2.25	1.07	250.4	0.0043
	1332	2.32	0.893	250.4	0.0036
Cd-109	88.04	1.22	0.882	42.65	0.021
Ba-133	81	1.51	19.47	1509	0.013
	276	1.36	2.520	1509	0.0017
	303	1.36	5.613	1509	0.0037
	356	1.41	15.03	1509	0.010
	384	1.53	2.109	1509	0.0014
Cs-137	662	1.82	15.33	1334	0.011

Table 4: Efficiency of CZT Detector

Source	Energy ($\pm$ 0.1 keV)	Resolution	Photopeak (cps $\times$ keV)	Total (cps $\times$ keV)	Photopeak efficiency
Na-22	511	1.20	25.4	2339	0.011

Table 5: Resolution HPGe Detector

Source	Energy ($\pm$ 0.1 keV)	Resolution keV
Na-22	511	2.83
	1274	2.75
Mn-54	835	1.73
Co-57	122	1.05
	136	1.06
Co-60	1173	2.25
	1332	2.32
Cd-109	88.04	1.22
Ba-133	81	1.51
	276	1.36
	303	1.36
	356	1.41
	384	1.53
Cs-137	662	1.82

was found to be excellent, with full-width, half-max (FWHM) typically in the range of 1-3 (see table 3).

6 References

References need to be cited in order of appearance in the report. This is NOT a bibliography. I do not want to know what students have read in the past that contributed, but what was specifically used in generation of the report. I would like to see Endnote used with the “numbered” style formatting.

Table 6: Resolution of CZT Detector

Source	Energy ($\pm$ 0.1 keV)	Resolution	Photopeak (cps $\times$ keV)	Total (cps $\times$ keV)	Photopeak efficiency
Na-22	511	1.20	25.4	2339	0.011

EndNote is available for free at `https://webapps.utk.edu/oit/softwaredistribution/`. At the end of this document, the Endnote output style is provided for reference.