## OBJECTIVES:

- Learn basic electronics used in radiation detection.
- Observe waveforms of input/output signals at various points in a counting system.
- Practice data analysis and error estimation.

## EQUIPMENT:

- Oscilloscope
- BNC-BNC Cabling
- NIM Rack
- Geiger-Mueller Detector
- High Voltage Power Supply
- Signal Splitter
- Amplifier
- Dual Counter/Timer
- Radioactive Source

## PRECAUTIONS:

- ***DO NOT CONNECT/DISCONNECT BIAS CABLES WITH THE HIGH VOLTAGE ENERGIZED: THIS CAN CAUSE DAMAGE TO THE DETECTOR OR ELECTRICAL SHOCK.***
- ***OBSERVE PROPER RADIOLOGICAL CONTROLS/PROCEDURES FOR WORKING WITH A SEALED CHECK SOURCE.***



LAB 2: Nuclear Instrumentation/Counting Statistics

## PROCEDURE:

1. Check the following operating conditions:
   a. NIM RACK:
      i. Check the GREEN LED is LIT.
   b. HIGH VOLTAGE POWER SUPPLY:
      i. Energized to an operating voltage of 0.90 KV.
   c. OSCILLOSCOPE:
      i. Energized.
   d. AMPLIFIER:
      i. Begin with course and fine gain settings as they are, with a negative polarity and a 2 μsec shaping time.
   e. COUNTER/TIMER:
      i. A counting time interval of 1 minute should already be established.
2. Place the Lantern Mantle source under the GM detector.
   a. Check that the system is registering counts (due to radiation) and then stop counting and clear the display.
3. Record the following output signal shapes using the oscilloscope by connecting it to the output point using the BNC-BNC cable provided (hint: start with AUTORANGE and then make manual adjustments).
   a. Observe and record the output from the SIGNAL SPLITTER (notice that EVERY pulse has the same amplitude and that the polarity is negative).
      i. In Figure 1, draw the waveform of the output from the Signal Splitter. Record the voltage per division 0.5 (V/div), time per division 1.0 (msec/div), negative amplitude 1.78 (V), rise time 0.2 (msec), and fall time 2.0 (msec).

**Fig 1. Signal Splitter Output**

b. Observe and record the UNIPOLAR and BIPOLAR output from the AMPLIFIER:

i. In Figure 2, draw the waveform from the UNIPOLAR output and record voltage per division 500 (mV/div), time per division 5.00 (μsec/div), positive amplitude 1.25 (mV), rise time 3 (μsec), fall time 3 (μsec), overshoot amplitude 150 (mV), and overshoot time 6 (μsec).

Fig 2. Unipolar Output Ch2

ii. For Figure 3, draw the waveform from the BIPOLAR output and record the voltage per division 20.000 (mV/div), time per division 5.00 (μsec/div), the positive amplitude 20.000 (mV), the negative amplitude 15000 (mV), duration 13 (μsec), overshoot amplitude 8.000 (mV), and overshoot time 5.00 (μsec).

Fig 3. Bipolar Output

Record the following amplifier settings:

Course Gain: 100 Fine Gain: 0.1 Amplification: 100

iii. While looking at either bipolar or unipolar output, change the SHAPING TIME setting to values lesser and greater than 2 μsec. Describe how the output pulse is affected in timing, amplitude, and integrated charge characteristics (area under the curve).





c. Observe and record the output from the SCA:

i. For Figure 4, draw the waveform from the single channel analyzer and record the voltage per division 2 (V/div), time per division 5us (~~nsec/div~~), positive amplitude 5.4 (V), and wave duration 1us (nsec).

Fig 4. SCA Output

4. Turn off and disconnect the oscilloscope. Re-establish the counting chain wiring.
5. Change the counter to a 30-second protocol. Put the Cs-137 check source in place.
6. Record fifteen 30-second counts in the following table. You will use these for statistical analysis in the lab questions.

Table 1

| | | | |
|---|---|---|---|
| 1 | 592 | 9 | 593 |
| 2 | 615 | 10 | 648 |
| 3 | 653 | 11 | 623 |
| 4 | 632 | 12 | 580 |
| 5 | 577 | 13 | 628 |
| 6 | 565 | 14 | 624 |
| 7 | 619 | 15 | 651 |
| 8 | 619 | | |

602
627

7. Change the counting protocol to 5 minutes.
8. Record a single five-minute gross count (with the source in place) and another five-minute background count. These data will be used for statistical analysis.

Five-Minute Gross Count: 6125 Five-Minute Background Count: 95

9. Switch the High Voltage Power to OFF.
10. Turn off the NIM-bin power.

**QUESTIONS:**

***Include the Names of your Lab Partners and note that each Individual is responsible for creating their own report.***

**1. In the space provide, draw a schematic diagram of the nuclear counting system that you used in this laboratory exercise. Label major components (a through f) in the figure. Name them and describe their function below.** picture of equipment

a. ______

b. ______

c. ______

d. ______

e. ______

f. ______





**2. Based on the waveforms you recorded in Figures 1 - 4, answer the following questions:**

**a. What is the polarity of the signal coming out of the SIGNAL SPLITTER? Give a brief explanation as to why.** Unipolar

**b. What is the difference between the UNIPOLAR and BIPOLAR amplifier output? What is the primary reason for using bipolar pulses?**

**3. Using your recorded data (Table 1), calculate the following (ignore background):**

**a. Minimum – Maximum:** 565 - 653

**b. Mean:** 614.6

**c. Variance:** $s^2 = 760.5$ → Variance $\sqrt{s^2} = 27.57$ ← $s^2 = \sum_{i=1}^{N} \frac{(x_i - \bar{x}_e)^2}{N-1}$

**d. Standard Deviation:** 24.791 (sq root of the mean)

**e. Chi-square statistic:** 17.31 ← $\chi^2 = \frac{(N-1)s^2}{\bar{x}_e}$

**f. Chi-square p-value:** 0.326 (interpolated) ← use chi square chart

**g. 95% confidence interval for a 30-second count:** 614.6 ± 12.5    602 (phone) 627.1

**h. How many of your 15 gross counts fall within the 95% confidence limit?** 5

**4. Using your recorded five-minute gross and background counting data, calculate the following:**

**a. Recorded background counts:** 95

**b. MDA (for a 5-minute count):** 47.2 +95 → 142.2 cpm

**c. Recorded gross counts:** 6125

**d. Net counts (well above MDA?):** Yes, 5983

**e. Net count rate (per 30 seconds):** ÷ 10 × 2 = 598.3 per 30secs net

**f. Standard error of net count rate (per 30 seconds; think about this!):**

**g. Does the value of the recorded count, averaged over a 30-second time period, fall in the confidence interval established in 3.g above?**