Notes on Setting up Scintillation Counters

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Background

A charged particle passing through a solid piece of plastic containing an organic dye will cause a tiny flash of light. This flash of light is guided to enter a Photomultiplier tube (e.g. Hamamatsu 931A) powered by a high voltage base (e.g. Hamamatsu HC122). An input voltage of 5 to 8 volts is converted to a high voltage in the PM tube proportional to the input voltage. This high voltage creates a tiny (~ 20 mV) and transient (~ 10 ns) signal. The higher the voltage the larger the output signal. However, the higher voltage also creates more thermal noise signals.

These signals are sent to a DAQ (Data Acquisition unit) such as the QNET II board. The signal passes through an amplifier (10X) and then a discriminator where only signals with a peak voltage higher than a threshold voltage are allowed to produce an output pulse.

Typically, In order to reduce the effect of the noise signals, two PM tubes are used and only coincident signals from both are allowed to produce an output pulse. Each output pulse is usually set to last 50 ns and coincidence is defined to exist if a pulse from the first PM tube overlaps a pulse from the second.

There is a finite probability that even totally unrelated and random signal could happen to accidentally overlap and produce a coincidence signal in error. We would call this an “accidental”. This would depend on the width of the output pulse and the frequency of random signals called “Singles Rate”.

The Singles rates usually increase exponentially with the tube voltage and decrease exponentially with the discriminator voltage.

However, the coincidence rate while related exponentially, usually shows a plateau region where it doesn’t change very much as the voltages are changed a little. This is the region that is most optimum.

In order to find this region, we must maximize the sensitivity of both PM tubes (increasing the tube base voltages), and minimize the discriminator threshold voltages while minimizing the noise and hence the accidental rate.

Optimization:

Thus, there are 4 voltages for which we must find the optimum values. In addition, we will monitor the Singles rates for both PM tubes, the Coincidence rate, and the output pulse width. This is a complex task.

	Detector A	Detector B
PM Tube base input Voltage	V_{TA}	V_{TB}
QNET Discriminator Threshold Voltage	V_{DA}	V_{DA}
Singles Rate (counts / s)	R_A	R_B
Accidental Rate (counts /s)	R_{Ac}	
Coincidence Rate (cts / s)	R_{Co}	

General procedure:

1. Setup equipment,
2. Measure, record, and monitor all signals
3. Minimize changes to all other variables
4. Use the Oscilloscope and previous records to determine approximate starting values for all 4 voltages
5. Design a sampling plan for measuring statistically relevant coincidence count rates
    a. Use a time interval that will guarantee at least about 15 counts
    b. Repeat each measurement about 15 times (to reduce the sampling error to 25% = $1/\sqrt{15}$))
6. Vary V_{DA} (e.g. for QNET II use values from 0.2V to 0.5V in steps of 0.05V) while holding V_{TA}, V_{TB}, & V_{DB} constant.
7. Measure coincidence rate using your sampling plan
8. Graph data, look for the plateau, choose the optimum V_{DA} and leave it set at this optimum value hereafter.
9. Repeat steps 6-8 varying V_{DB}
10. Repeat steps 6-8 varying V_{TA}
11. Repeat steps 6-8 varying V_{TB}
12. Record Coincidence rate with optimum settings
13. Measure Singles rates for each Detector separately
14. Calculate estimated Accidental rates for each detector
15. Make sure that Error Percents = R_{Ac} / R_{Co} is reasonable
16. Repeat procedure as needed to get consistent and optimal results.
17. Document the entire procedure as part of Instrument Validation Process

Accidental Coincidences

The probability that both detectors could register coincidence of two random, unrelated signals is:

$P_{AB} = 2\ \tau^2\ R_A\ R_B$
Where:
τ = the output pulse width in seconds
R = the counts / seconds for each of the detectors

The number of time intervals of width τ that occur in each second is $1/\tau$.

Thus, the expected count rate per second of accidental coincidences is
$R_{Ac} = P_{AB} / \tau = 2\ \tau\ R_A\ R_B$

The percent error due to accidental coincidences would then be:
$E_{Ac} = R_{Ac} / R_{Co}$