## **R**ADIATION SOLUTIONS INC



## Pulse Pile-up and Pile-up Rejection.

Pulse pile-up happens when pulses arrives closer in time than the pulse resolution time for the system. Figure # shows an example of a  $1^{st}$  order pulse pile-up where pulse 2 is riding on the tail of pulse 1. When this occurs the system can't measure the pulse heights correctly. If the pulses are very close in time the system will simply record the two pulses as a single event with combined pulse amplitude (Pulse 1 + Pulse 2), this is also known as peak pile-up. If the pulses are spaced further apart the system may simply accepts both events and record them with incorrect pulse amplitude, this is known as tail pile-up. In either case the events will end up in the wrong energy channels and the spectrum will be contaminated leading to incorrect results when the spectra are further analyzed.



The number of pile-up events depends strongly on the count rate of the system. At lower count rate 1<sup>st</sup> order pile-up is dominant but as the count rate increases higher order pile-up where 3 or more consecutive pulses are involved becomes significant. The rate of pulse affected by 1<sup>st</sup> order pile-up is  $R_{PU}=R_T \times R_T \times 2\tau$ , where  $R_T$  is the true input count rate and  $\tau$  the pulse resolution time.

Figure ## shows the effect 10%  $1^{st}$  order peak pile-up has on a  $^{137}$ Cs spectrum. The clean spectrum has no recorded events above the photo peak at 662 keV whereas the pile-up spectrum has recorded events up to 2 x 662 keV. Higher order pile-ups will produced a peak a 3 x 662keV, 4 x 662keV etc. The result of tail pile-up is a much more blurred picture.

A good spectrometer will have build in pile-up rejection to minimize the effect of pile-up. The number of pile-up events will be smaller as the pulse resolution time gets smaller. Unfortunately as two pulses gets closer and closer it gets harder to separate them and at some minimum gab between consecutive pulses they can't be separated. Below some minimum resolution time,  $\tau_{min}$ , pulse pile-up can not be prevented. However, consecutive pulses with a separation between  $\tau_{min}$  and  $\tau$  can be detected and rejected.



The process of detecting and rejecting pulses is called "pile-up rejection". The minimum resolution time depends on the detector type, the front-end electronics, and the implementation of the pile-up rejector. A good pile-up rejection system has a  $\tau_{min}$  less than 400ns for a Sodium Iodide detector and  $\tau_{min}$  less than 100ns is only seen in the absolute top end of equipment, typically for laboratory use.

## How to test a pile-up rejector

Since the amount of pile-up depends on the incoming count rate the simplest way to test a system is to increase the count rate using a source such as <sup>137</sup>Cs with a single strong separate peak. Increasing the count rate by mowing the source closer to the xtal from around 10,000 cps until it becomes visible evident that pile pile-up is present, logarithmic plot will visually emphasize the pile-up. If there are no clear structure in the pile up spectrum above 662 keV it's an indication of either no pile-up rejection or a purely implemented pile-up rejector. If the pile-up spectrum looks similar to Figure ## the minimum resolution time can be calculated. If the counts in the primary <sup>137</sup>Cs peak are P<sub>0</sub> and the counts in the 1<sup>st</sup> order pileup peak are P<sub>1</sub> then the ratio of pulse affected by pileup 2P

to the true pulse rate is  $R = \frac{2P_1}{P_0 + 2P_1}$  remembering that each 1<sup>st</sup> order pileup pulse

involves two pulses. From above 
$$R = \frac{R_{PU}}{R_T} = R_T x 2\tau_{\min}$$
 and  $\tau_{\min} = \frac{P_1}{R_T (P_0 + 2P_1)}$ . In

order to correctly calculate  $\tau_{min}$  it's important to ensure that  $R_T$  corrected for dead time.

## What are the implications of pile-up?

Pile-up is only a problem a higher count rates. Events are recorded in the wrong channels higher up in the spectrum when pileup occurs. K40 can be pileup into the uranium and thorium window and leading to incorrect concentrations after spectrum stripping.