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Introduction

The purpose of this application note is to test the signal processing performances of a readout system composed by the CAEN N1068 shaping amplifier **[1]** and the CAEN N6741 peak sensing ADC **[2]**. Spectra have been collected for ^{137}Cs source, measured with a lanthanum bromide scintillator ($LaBr_3$), by both feeding the $LaBr_3$ output directly to the N1068, using the "0.5 Fast" option, and using a charge sensitive pre-amplifier A1424 **[3]** for the pre-amplification stage.
The resulting spectra have been analyzed with *ROOT Data Analysis Framework* **[4]** in order to test the goodness of the spectra resolutions.

Material and Methods

Instrumentation Overview: N1068 Spectroscopy Amplifier

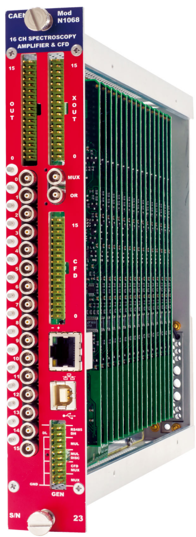


Fig. 1: N1068 Spectroscopy Amplifier.

The N1068 (Fig. **1**) is a shaping amplifier with 16 channels, individually programmable. Events are selected through a 30% constant fraction discrimination (CFD) and it is possible to perform pile up rejection.

The input signal, before being shaped into a Gaussian, enters a polarity section where a positive or negative input polarity is selected. This stage is followed by the energy and timing sections, with the first one being a CR-RC circuit with programmable time constants or shaping times. The available shaping times are: **0.5 Fas**t for non preamplified signals, **0.5 µs, 1 µs, 2 µs and 4 µs**. The energy section contains also the pole zero compensation, an 8 step coarse gain (x2, x4, x8, x16, x32, x64, x128, and x256), a fine gain (from 0 to 255) and a DC restore circuit.

The timing section is a timing filter with a succession of a differential stage and an integration stage both with two different time constants. The timing signal can be amplified up to four times its magnitude and then sent to the CFD section. The CFD technique is based on summing a delayed input signal to an attenuated and inverted one, the timing information is then given by the zero crossing point. In order to obtain a correct output, the maximum of the attenuated signal must cross the delayed signal at the selected amplitude fraction, in our case 30%. In the N1068 *the delay time is settable for each channel by a 5 step jumper* **[1]**, where the steps correspond to: 8, 16, 24, 32 and 40 ns delay, with 8 ns corresponding to the leftmost step. For a correct functioning, the jumper must be set accordingly to the formula $T_{Delay} = T_{rise} \cdot (1 - F)$, where T_{Delay} is the delay time, T_{rise} is the rising time of the Timing signal and F is the constant fraction value (30%). The Timing signal can be seen in an oscilloscope device by programming the MUX output.

In our case, the Timing signal had a rising time of approximately 140 ns (Fig. **2**), and following the previous equation, T_{Delay} should be 98 ns. Even though this value is considerably higher then the maximum T_{Delay} settable with the jumper, we found that it was possible to obtain good measurements keeping the jumper in the step corresponding to 40 ns.

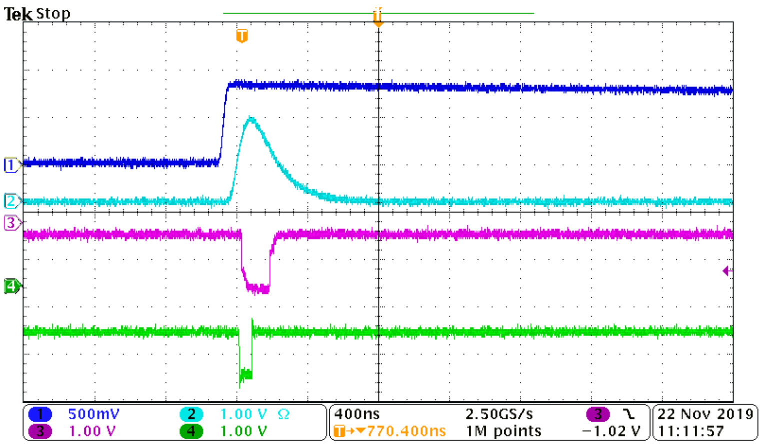


Fig. 2: Oscilloscope screenshot showing the preamplified input (blue), the Timing signal (cyan), the OR output (magenta), and the CFD output (green). The jumper of the CFD delay is referred to the Timing signal.

All the described parameters can be manipulated through the CAEN *Spectroscopy Amplifier Control Software* (CAEN-CSA) [**5**] or directly from the terminal (for example using Teraterm [**6**]), along with the PUR parameter which enables the pile up rejection option. When the pile up rejection is enabled, every time a pile up event occurs, the energy output of the N1068 is set to saturation value. Fig. **3** shows an example of a rejected pile up event.

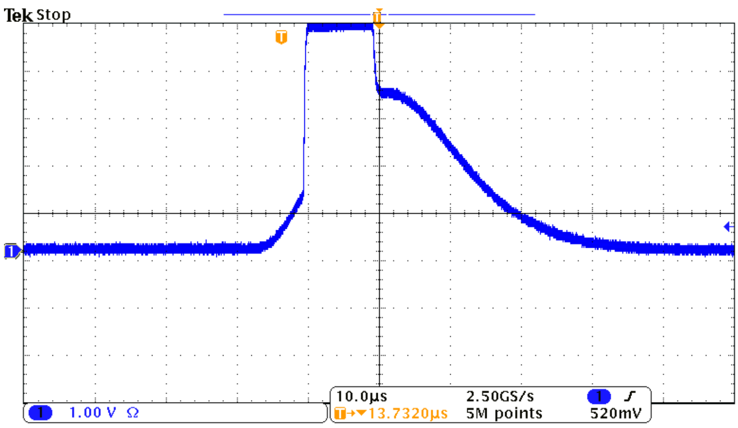


Fig. 3: Pile up rejection example.

For a more detailed explanation of the N1068 parameters and its operating modes refer to the user manual **[1]** and to Sec. **Measurement Setup**.

Instrumentation Overview: N6741 Peak Sensing ADC

N6741 (Fig. **4**) is a peak sensing ADC, belonging to readout systems based on a mixed analog to digital acquisition chain, combining a high channel density with a low dead time. The peak measurement approach is to use a moderate ADC sampling frequency to sample the input and to apply proprietary algorithms implemented in the FPGA (field programmable gate array) to evaluate the Gaussian height.

The digital pulse processing calculates the height of the Gaussian signal. Values are sent to the software that generates the energy spectrum up to a limit of 16k channels. The peak sensing ADC has a low Differential Non-Linearity thanks to the sliding scale method. The differential non linearity is an important error source in the acquisition process, the sliding scale smooths this effect by continuously adding a slowly varying known DC offset to the analogic input and then subtracting the correspondent digital quantity after the conversion. The height of the signal is calculated inside a gate, which can be given externally or, provided an external trigger, can be programmed by specifying its length in the peak sensing configuration file.

In addition to the gate length, the peak sensing configuration file contains all the parameters necessary to configure the N6741, in particular, it is possible to specify the desired number of spectrum channels, enable or disable the sliding scale option, or set the input range (4V/8V) and the Zero Suppression (ZS) threshold. A more detailed description of the peak sensing configuration is available in the N6741 User Manual **[2]**.

Fig. 4: N6741 Peak Sensing ADC.

Measurement Setup

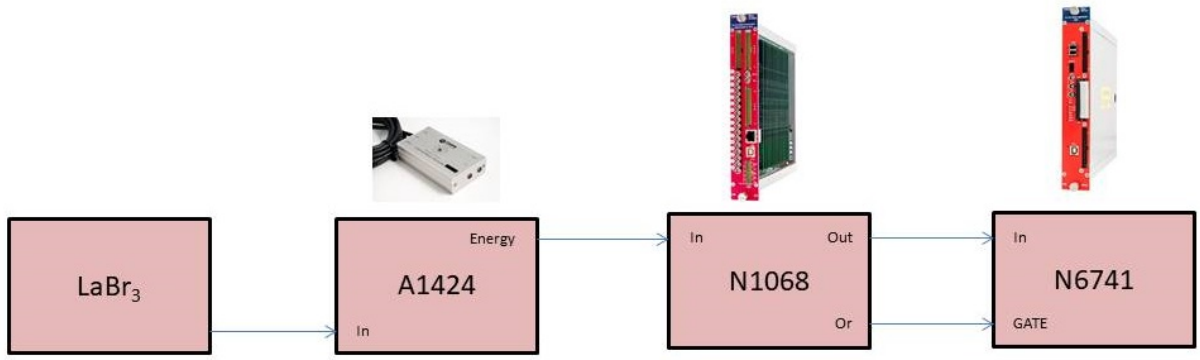


Fig. 5: Set up scheme.

The photons from ^{137}Cs source were collected with a $LaBr_3$ scintillator. Measurements have been taken using all the N1068 shaping time available; in the case of a shaping time of "0.5 Fast" (0.5F) the signal from the scintillator was sent directly to the N1068 shaping amplifier, while a preamplification stage was needed for all the other cases (we used a A1424 preamplifier **[3]**). The Gaussian signal from the N1068 was then fed to the N6741 peak sensing ADC, along with the output signal from the OR port, which gives the gate starting point. A scheme of the experimental set up, including the preamplifier, is shown in Fig. **5**.

It must be pointed out that the peak sensing cannot compensate offsets in the signal from the shaping amplifier, so for a good measurement any offset must be corrected in the N1068 by adjusting it through *terminal emulator* or using the *Spectroscopy Amplifier* software. Fig. **6** shows two oscilloscope screenshots, one of a correct energy signal (right panel) and one of an energy signal with an offset of around -32 mV (left panel).

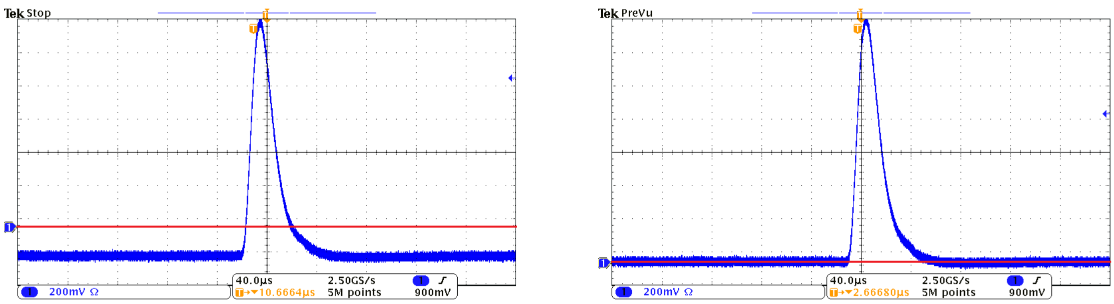


Fig. 6: Oscilloscope screenshot for energy signal with an offset of approximately -32 mV (left) and without offset (right). A red line helps to visualize the corresponding offset with respect to zero.

Another parameter that must be set correctly is the threshold, which controls the DC restorer of the shaping amplifier. In particular, the N1068 threshold parameter was chosen to be as small as possible to not cut out a significant energy portion from the spectrum, while still allowing a correct measurement. This preliminary operation was carried out by connecting the MUX and OR ports of the N1068 to an oscilloscope and increasing the threshold value until only one OR signal is present for any Gaussian (Fig. **7**).

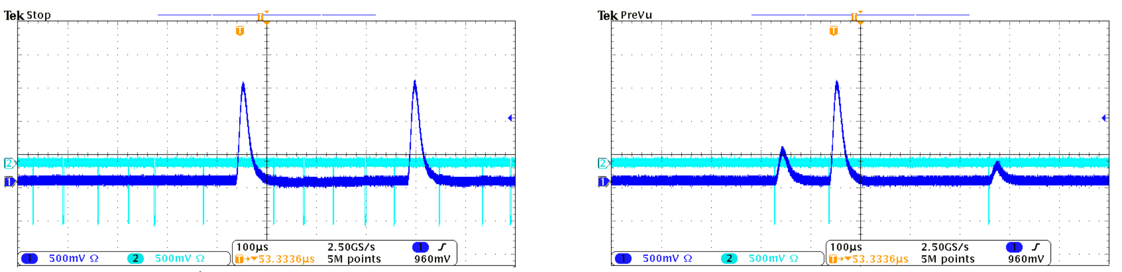


Fig. 7: Oscilloscope screenshots showing an example of a too low threshold value (left) and a good threshold value (right). The blue signal in the figure is the Gaussian, while the cyan one is the OR output which in the case of a single channel, corresponds to the CFD output.

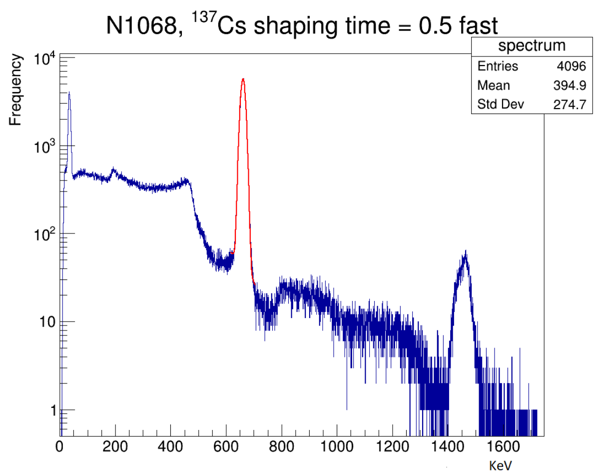
The parameters for the shaping amplifier and the peak sensing are summarized (Tab **1**).

N1068 Setting	No Preamplifier (0.5F)	With Preamplifier
CFD delay jumper	40 ns	40 ns
Gain	64	32
Fine Gain	50	40
Pole zero	50 µs	100 µs
T_{gain}	4x	4x
T_{Int}	20 ns	20 ns
T_{diff}	100 ns	100ns
Threshold	67 mV	6 mV
CFD output delay	0 ns	0 ns
CFD output width	0 ns	0 ns
OR output width	31 ns	31 ns
PUR	active	active
Offset	126 mV	126 mV
N6741 Settings	**Value**	**Value**
Number of channels	4096	4096
Sliding scale	active	active
Input range	8V	8V
ZS threshold	0	0

Tab. 1: Table showing the settings of the N1068 shaping amplifier and the peak sensing configuration file for the collection of the spectra of ^{137}Cs with a $LaBr_3$ scintillator.

Results

Energy spectra of ^{137}Cs source are shown in Fig. **8** (figure on top is without preamplifier, while the remaining four figures with preamplifier) for all the available shaping time. In addition to the characteristic 662 KeV ^{137}Cs gamma peak, the spectra show also the x-rays peaks of ^{137}Cs and Lanthanum, at 32 keV and 35 keV, respectively. Their energies are too close to be resolved with a $LaBr_3$ detector and they often appear as a single peak in the low energy region. The two peaks of ^{137}Cs were used to perform an energy calibration for each case.



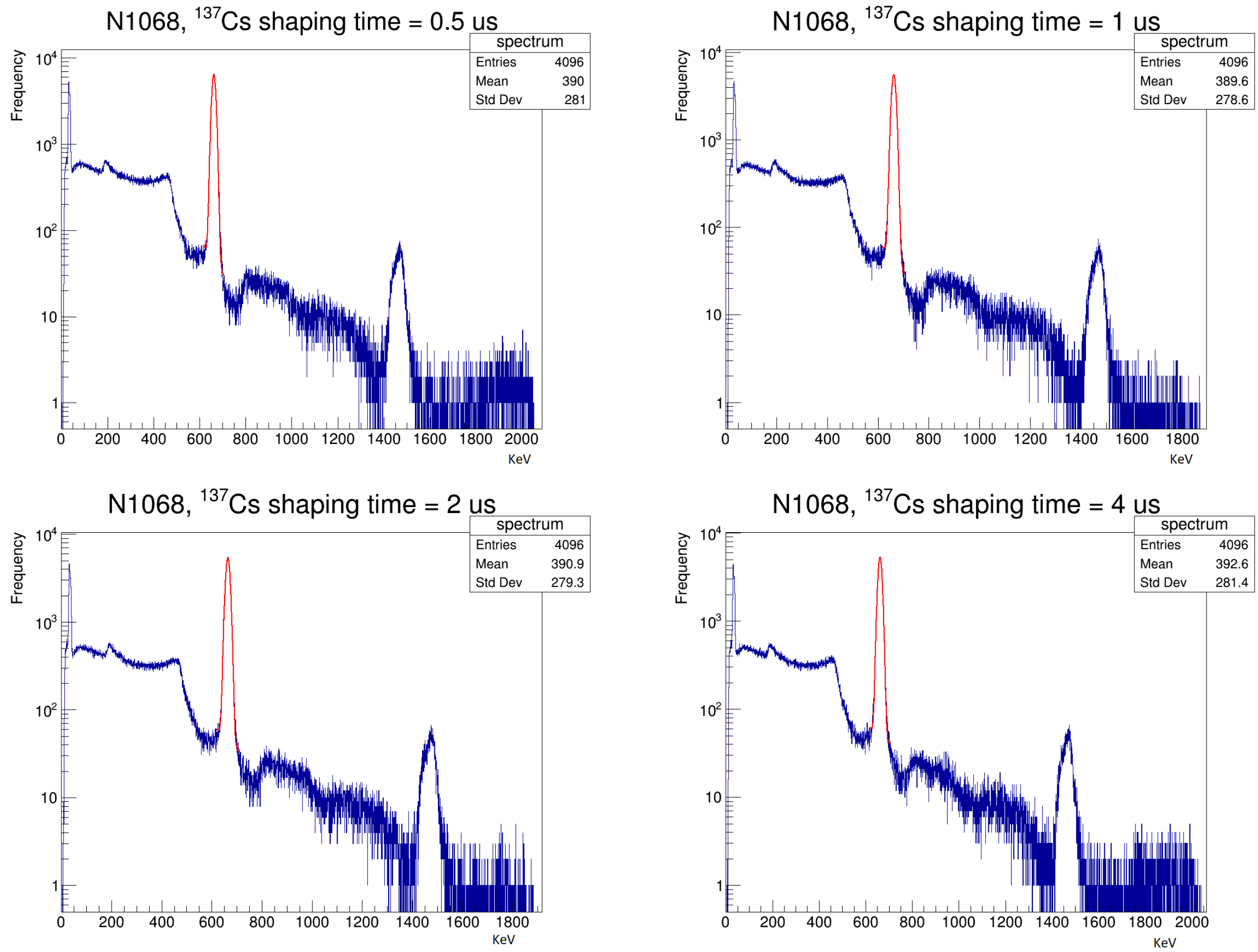


Fig. 8: ^{137}Cs spectra taken for 0.5F, 0.5 µs, 1 µs, 2 µs and 4 µs shaping time. A1424 preamplifier has been used but for the 0.5F option.

Spectra resolutions were estimated by fitting the 662 KeV ^{137}Cs peak with a sum of a first order polynomial and a Gaussian. In the case of ^{137}Cs measured with $LaBr_3$, the expected resolution is 3.0 %. The calculated resolutions are always in agreement with this expectation and are listed in Tab **3** along with the FWHM of the peak.

Shaping Time	FWHM at 662 KeV	Resolution
0.5F	20.4 $\pm$ 0.1 KeV	3.1 $\pm$ 0.1 %
0.5 µs	20.1 $\pm$ 0.1 KeV	3.0 $\pm$ 0.1 %
1 µs	20.3 $\pm$ 0.1 KeV	3.1 $\pm$ 0.1 %
2 µs	20.5 $\pm$ 0.1 KeV	3.1 $\pm$ 0.1 %
4 µs	20.7 $\pm$ 0.1 KeV	3.1 $\pm$ 0.1 %

Tab. 3: Calculated FWHM and resolutions.

Conclusions

Spectra of ^{137}Cs have been collected for all the possible values of the shaping time of the N1068 in the 4K channels spectrum configuration of the N6741. In all the cases the spectrum shapes are in good agreement with the expectations; in addition it was possible to reveal a good range of energies, as the presence of the X-ray peaks of lanthanum and cesium confirmed. The spectra have been fitted in order to calculate the resolutions, obtaining values in agreement with the expectations for all the cases.

References

[1] UM3148 – N1068 User Manual.

[2] UM7493 – N6741 User Manual.

[3] DS2634 – A1424 Scintillation Preamplifier Data Sheet.

[4] Rene Brun and Fons Rademakers. "ROOT - An Object Oriented Data Analysis Framework". In: *Proceedings AIHENP'96 Workshop, Lausanne, Sep. 1996, Nucl. Inst. and Meth. in Phys. Res. A*. Vol. 389. 1997, pp. 81–86. URL: http://root.cern.ch/.

[5] CAEN Spectroscopy Amplifier Control Software User Manual.

[6] Teraterm terminal emulator. URL: https://ttssh2.osdn.jp.

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