Krambi diode test

AS

July 31, 2013

Abstract

Tests with diode

1 Setup & results

Two channel division used due to saturation of the GP7's dynamic range. Some other characteristics and comparison to standard GP7 usage:

- Capacitance of 17 pF (normally used with $\sim$ 1 pF)
- Current of 400 nA/-150 V, 500 nA/-200 V, 540 nA/-250 V (normally 100 pA or less)
- Because of the current, AC coupling with 1 nF capacitor
- Front end at -1.3 V (a gate above AVSS) encourages usage of signal division rather than driving portion of signal to ground.
- For divison to work, resistance similar to input impedance must be used in series with signal path. From previous experiences these are around 1 kΩ which was well confirmed below
- To reduce input impedance, operating point of the chip was shifted with loaded prebias at around 4 mA; normal setting is 0.5 mA.
- Best performance for high vfp, which is the bias that sets the resistance R of the feedback in the pre-amp. Between -800 and -1000 mV used (normal setting is -700 mV).
- It is hard to gauge the noise, mostly because both resistance and capacitance are changing. Even assuming fixed resistance, a noise of 4500 e would not be exceptional. At a gain increase of 10 this would equate to about 4 keV resolution.
-

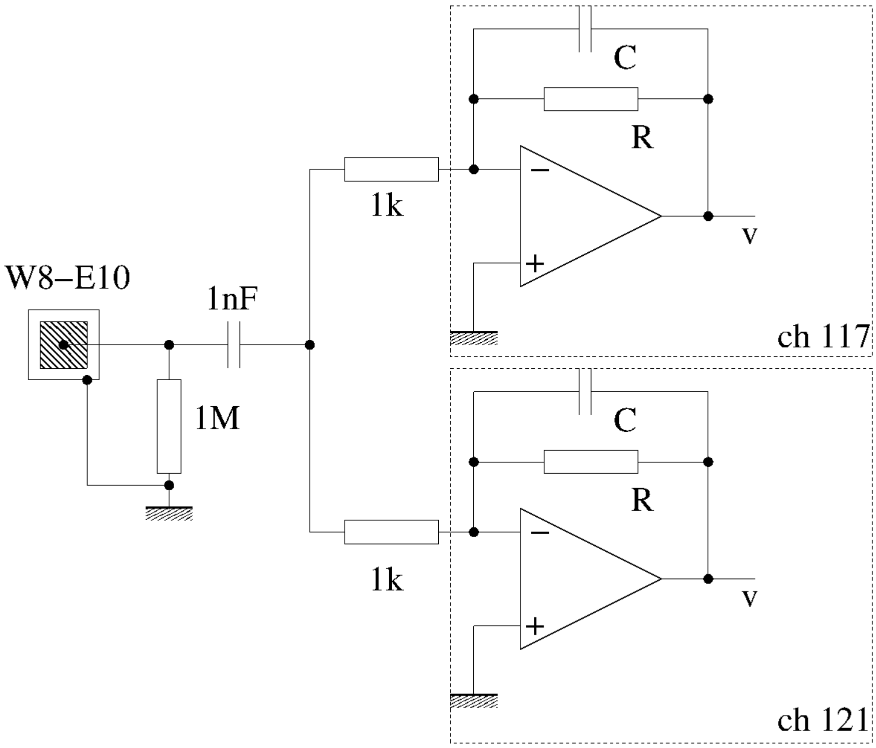

Figure 1: Schematic of the receiving circuit.

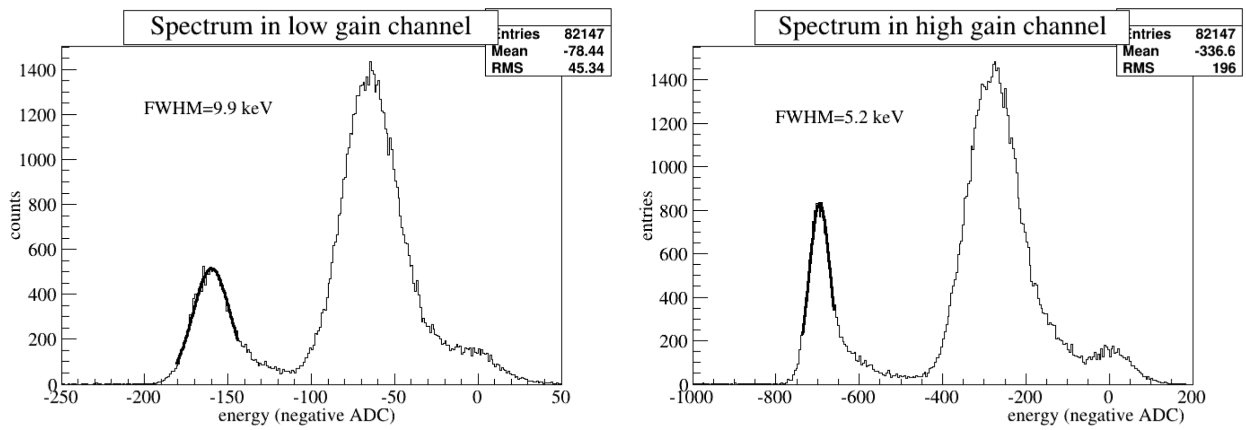

Figure 2: Spectra in both connected channels. One seems to have lower resistance than the other and the amount of charge is quadrupled relatively to the other channel. In the high gain channel resolution might be underestimated due to saturation effects. At 160 V negative.

2 Noise analysis

For CR-RC the expected noise in equivalent noise count is:

$$Q^2(ENC) = \frac{\mathrm{e}^2}{8}\left(e_a^2 C^2 \frac{1}{\tau} + i_a^2 \tau\right) \tag{1}$$

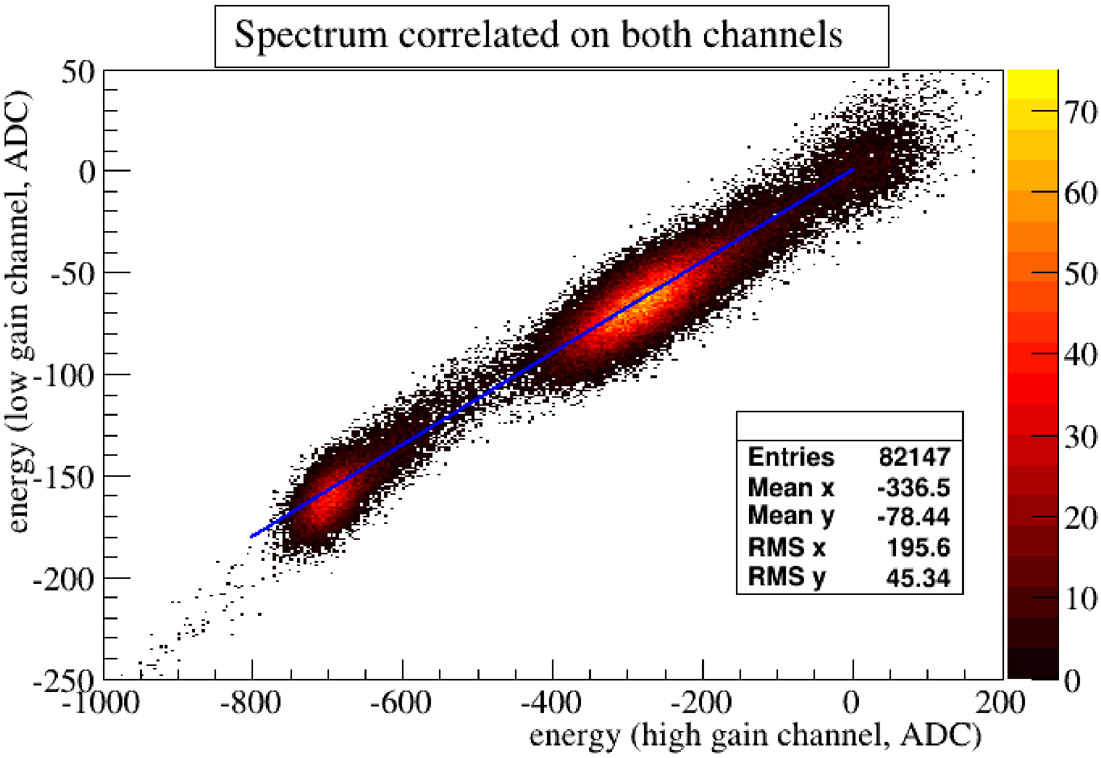

Figure 3: Correlation of collected charge in both channels. Line with a slope of 0.25 overlaid as a guidance. The correlation is well perserved until the saturation effects become apparent in the high gain channel. At 160 V negative.

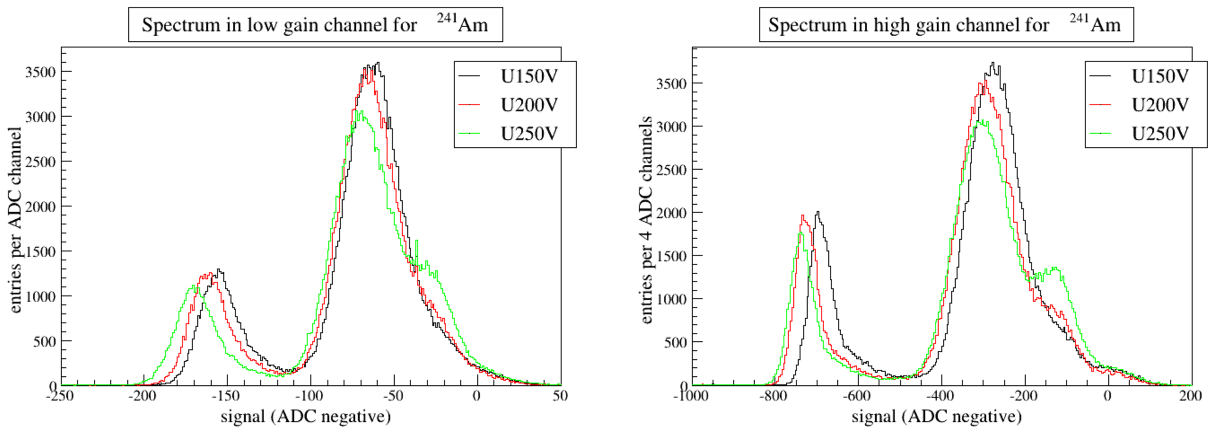

Figure 4: Voltage scan: The same data recorded at -200 V. Little difference observed relative to -150 V, mostly in high gain channel.

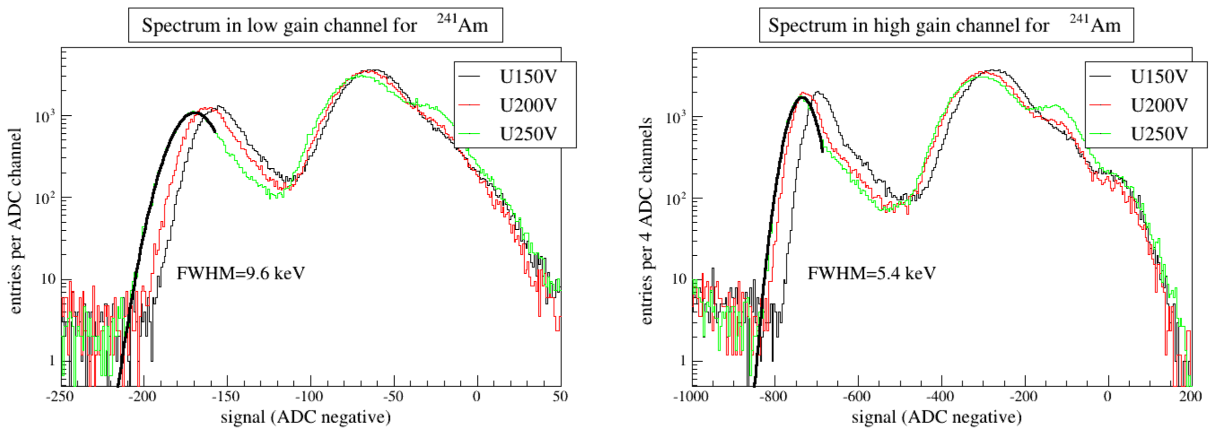

Figure 5: Fit of a Gaussian function to the photopeak in the spectrum in the low (left) and high (right) gain channel.

where

- e_a^2 is the parallel/voltage noise contribution

$$e_a^2 = e_{a,0}^2 + 4kTR_s \tag{2}$$

  with $e_{a,0}^2$ the contribution of the ASIC and R_s series resistance, k is Boltzman constant and T the temperature.

- i_a^2 is the series/current noise contribution

$$i_a^2 = 2e_0 I + \frac{4kT}{R_b} \tag{3}$$

  with I the dark current of the diode, R_b the bias resistor and e_0 unit charge.

- τ is the shaping time
- C is the total capacitance seen by the input
- e is the Euler constant.

Paralel noise. For input DC bonded to the standard SINTEF/Hamamatsu sensor the noise of the slow, 500 ns shaper was found to be around 2 keV FWHM, seen as the width of the 60 keV photopeak line in ^{241}Am spectrum. Converted to ENC via division with 3.6 eV/pair and further by 2.35 to move from FWHM to RMS, this equates to Q_0=236 e ENC. Assuming negligible current contribution (at 1 pA level), absence of bias resistor and negligible series resistance, and typical trace capacitance of 1 pF, pure amplifier noise can be calculated to be:

$$e_{a,0}^2 = \frac{Q_0^2 \tau}{C^2} \frac{8}{\mathrm{e}^2} = 8 \times 10^{-16}\ \mathrm{V}^2\mathrm{s} \tag{4}$$

This can than be compared to constribution of a 1 kΩ series resistance:

$$e_R^2 = 4kTR_s = 1.5 \times 10^{-17}\ \mathrm{V}^2\mathrm{s} \tag{5}$$

which can, for most cases, be ignored. At 17 pF and τ=500 ns, the parralel contribution would be:

$$Q_p^2(ENC) = \frac{\mathrm{e}^2}{8}\frac{e_{a,0}^2 C^2}{\tau} = \Big(4000\ e_0\Big)^2 \tag{6}$$

Series noise. The dominating contribution is the dark current (at I_{meas} ~500 nA). For a multiplication diode, the contribution is given as

$$i_I^2 = 2m^2 e_0 I_{gen} \tag{7}$$

where I_{gen} is the generation current and m is the multiplication factor. The generation current is calculated as I_{meas}/m, so for m~10:

$$i_I^2 = 2me_0 I_{meas} = 1.6 \times 10^{-24}\ \mathrm{A}^2\mathrm{s} \tag{8}$$

Contribution of the bias resistor of 1 MΩ is an order of magnitude smaller and hence negligible:

$$i_R^2 = 4kT/R_b = 1.6 \times 10^{-26}\ \mathrm{A}^2\mathrm{s} \tag{9}$$

The series contribution is so (at 500 ns, worse case scenario) :

$$Q_s^2(ENC) = \frac{\mathrm{e}^2}{8} i_I^2 \tau = \Big(5400 e_0\Big)^2 \tag{10}$$

Total expected noise is current dominated and equates to 6700 electrons ENC. Equivalent expected energy resolution via multiplication with 2.35 and 3.6 eV/pair is 5.7 keV.