MAPIC: Multichannel Analysis and Wireless DAQ for the APIC

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1 Introduction

The aim of this project was to add a multichannel analysis function to the APIC and perform wireless readout. The APIC employs a preamplifier and a pulse shaper in order to transform delta function pulses from detectors into semi-Gaussian pulses with a shaping time of either 25ns or 450ns. These can be sampled with a fast but expensive commercial MCA. To reliably sample peak amplitudes with a cheap ADC, we employed a pulse stretcher circuit and a Micropython MCU. The purpose of this combination was to stretch the APIC pulses to a few microseconds so that they could be sampled with one of the three 12 bit ADCs on the "Pyboard" which each had a maximum sampling frequency of 2.4MSPS. The Pyboard also contained an onboard Wi-Fi chip that we could use for wireless readout.

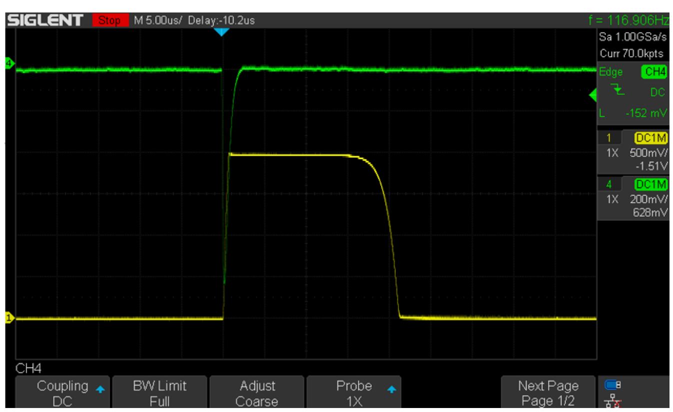

Figure 1: Pulse stretcher output. Green line is the 450ns semi-Gaussian output pulse from the APIC, the yellow line is the stretched square pulse from the pulse stretcher board.

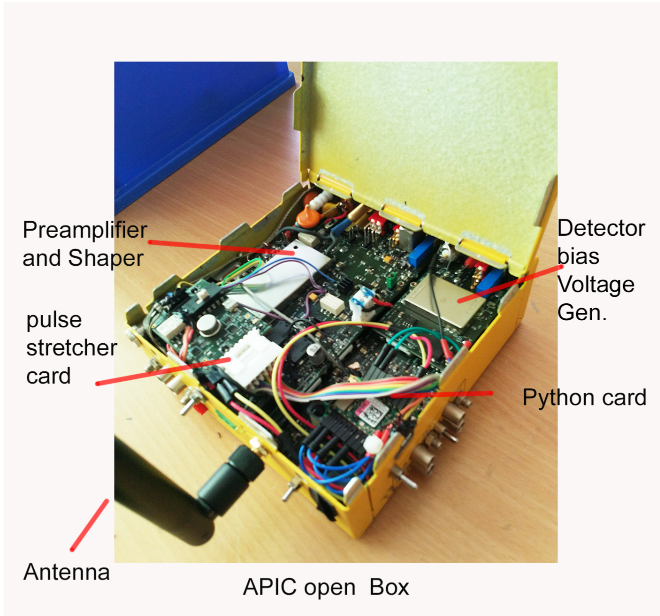

Figure 2: APIC box with Python card and pulse stretcher installed.

2 Method

In order to sample the stretched pulses, two methods were employed. Firstly we used an external hardware interrupt on a GPIO pin to trigger an ADC reading at the Micropython level - the light Python wrapper of the boards driver code. In the ISR, we also sent the data in a buffer via UDP network sockets over the Pyboard's wireless access point. The second method utilised the STM32 C drivers, which access the low level functions of the chip and contain features not supported in Micropython. We used the DMA to transfer converted values from the ADC into a buffer. Iterating through this buffer we detected peaks, sampled their amplitudes and enqueued the data for sending. This method presented faster sampling rates as it was implemented in compiled C code, however we only produced one sample per peak due to light ISR requirements. Using the Micropython method we took four 16 bit samples of each peak and averaged them. With the STM32 driver code, we also measured the time in CPU ticks and bundled this with the ADC count in two 32 bit numbers. In order to test these ADC sampling methods, we measured energy spectra from two radioactive sources and the regular pulses from an external DAC. The two energy spectra measured were: the energy spectrum of α radiation from ^{241}Am measured with a pin diode, and the energy spectrum of X-ray radiation from ^{55}Fe in a GEM (Gas Electron Multiplier) detector.

3 Results

The results of these experiments are summarised below in figures 3, 4 and 5. It should be noted that figures 3 and 4 were produced with the Micropython ADC sampling method and so we were limited to source rates of less than 2kHz. This limit was discovered to be a result of the sampling routine requiring a stretched peak of 75us for 4us of ADC sampling, in order for Micropython overhead to execute (e.g. the ADC/ISR starting), and because the Micropython code would give a runtime error if there was event pileup, which is likely for high-rate, random events. This limitation was the driving force for perfecting the high-rate DMA-ADC sampling displayed in figure 5, the sampling frequency of which was found to exceed 50kHz on regular pulses.

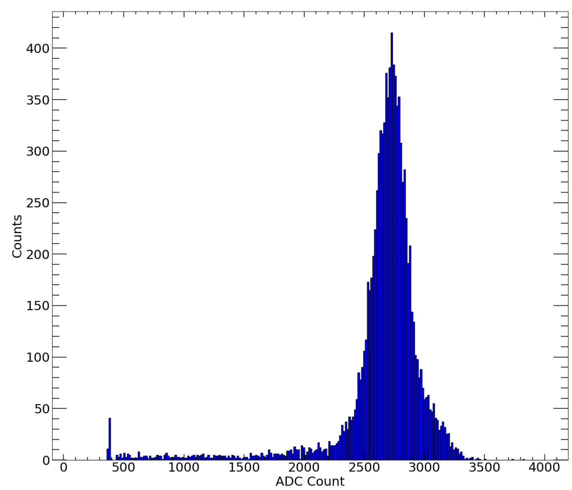

Figure 3: ^{241}Am α energy spectrum sampled with a pin diode, 10,000 events.

Figure 3 exhibits the expected 59.5keV α Bragg peak which agrees with the literature [1]. Although shows that our sampling method works, the result does not give us much more information about our readout system. On the other hand, the energy spectrum measurement of ^{55}Fe with a GEM detector is a more useful experiment as there should be two peaks: a main peak and an escape peak caused by the interaction of X-rays with the $ArCO_2$ gas. These two peaks have energies of 2.9keV and 5.9keV respectively [2], and allow us to calibrate the ADC count of our system. Additionally, the FWHM of the main peak can be used to calculate detector efficiency. Although we can see the two peaks in Figure 4 at around 1100 and 3000 with a detector efficiency of 27%, they are not in a 2:1 ratio. This suggests that we need to calibrate the gain profile of the pulse stretcher and the ADC. We observed a linear transfer curve at pulse stretcher outputs of less than 3V, however it was not directly proportional and there was an offset, both of which are required to be taken into account to correct this energy spectrum.

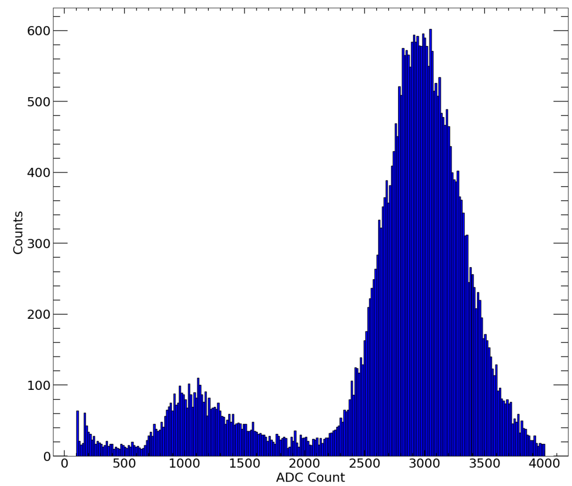

Figure 4: ^{55}Fe X-Ray energy spectrum obtained from a GEM detector, 100,000 events with overflow cut below 100 and above 4000 ADC counts.

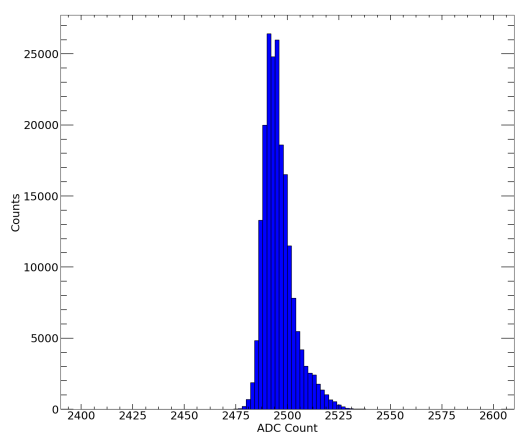

Figure 5: Regular DAC peaks with a ADC count of 2500 at a frequency of 50kHz.

Figure 5 shows the results of sampling regular DAC pulses at a rate of 50kHz with the faster STM32 C driver method which proves that, at least for these regular pulses, this sampling method is successful. It should be noted that this needs to be tested on the GEM detector with a high rate source to prove that this method can be used on a real detector. Furthermore, this wireless readout has been adapted to allow wireless control of the APIC box peripherals such as I2C digital potentiometers or the interal test pulses.

4 Conclusion

Overall, we have succeeded in our goal to perform wireless readout from and control of the APIC with the Pyboard by implementing high performance peak-finding routines and Micropython code. Additonally, we have tested our readout system by successfully sampling the energy spectra of two different radioactive sources, however as in any short project there are several avenues for further investigation. These include implementing a calibration method to correct the ^{55}Fe spectrum, testing the high performance readout method on the GEM detector with a high rate ^{55}Fe source and investigating the "triple interleaved" sampling method (7.2MSPS) which could sample the APIC shaper pulses directly.

References

[1] G Manzo, S Giarrusso, A Santangelo, F Ciralli, G Fazio, Santina Piraino, and A Segreto. The high pressure gas scintillation proportional counter on-board the bepposax x-ray astronomy satellite. *http://dx.doi.org/10.1051/aas:1997139*, 317, 04 1997.

[2] Z Ahmed, M A Bowles, R Bunker, S R Golwala, D R Grant, M Kos, R H Nelson, A Rider, R W Schnee, D Sotolongo, B Wang, and A Zahn. A prototype low-background multiwire proportional chamber. *Journal of Instrumentation*, 9(01):P01009–P01009, jan 2014.