Digital Multi Channel Analyzer Enhancement

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Introduction

A cement analyzing system based on radiation spectroscopy had been developed [1], using novel digital approach for real-time, high-throughput and low-cost Multi Channel Analyzer (MCA). The performance of the developed system had a severe problem: the resulted spectrum suffered from lack of smoothness, it was very noisy and full of spikes and surges, therefore it was impossible to use this spectrum for analyzing the cement substance. This paper describes the work carried out to improve the system performance.

Description of the Work

A Multi Channel Analyzer system, developed by NRCN, was used in the X-ray Fluorescence (XRF) instrument which had been designated for cement analysis. The MCA is built of a number of components: 12-bit high-sampling-rate Analog-to-Digital Converter (ADC) which can sample up to 48 Msample/sec, Field Programmable Gate Array (FPGA), embedded micro-controller, clock generator, keypad, LCD and memory. Each time the XRF instrument is powered on, the FPGA is programmed by a "setup memory". Once the FPGA is programmed it functions as a sophisticated hardware device performing complex logic operations.

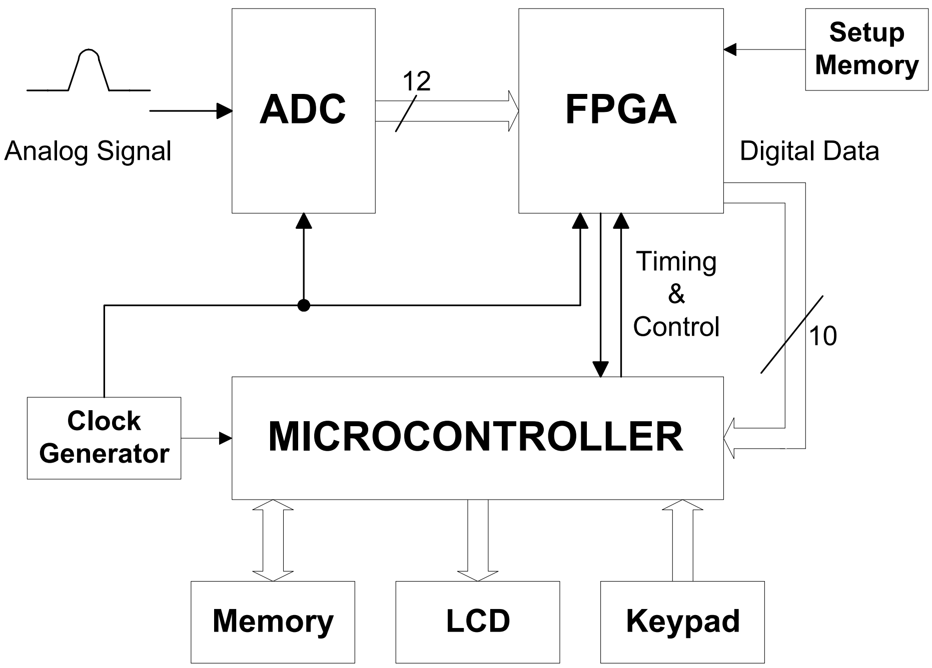

Fig. 1: Block diagram of the MCA

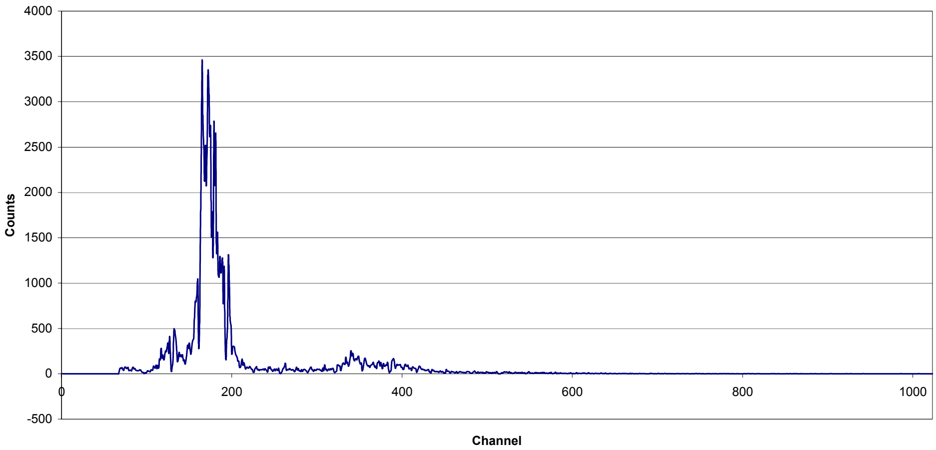

Fig 2. A spectrum of cement as was recorded by the MCA

The spectrum obtained by the MCA is shown in Fig. 2. As can be observed, the spectrum quality is rather poor, and this spectrum can not be used to analyze the cement elements. The challenge was to improve the spectrum without changing the MCA hardware. To this end, the FPGA flexibility was used, complemented with software modification in the analysis computer program. After examining thoroughly the MCA performances, we concluded that there is a Differential Non-Linearity (DNL) problem common to sampling and successive approximation ADC's. This problem was approached from three different angles. Two angles manipulated the sampled data by hardware (FPGA) while the third angle handled the whole spectrum using software only.

1. ***Averaging*** - Five samples around the maximum value were averaged to obtain the peak of a single pulse.
2. ***Filtering the samples*** - The power spectrum density of the samples' stream was analyzed and flittered by an adjusted Butterworth filter.
3. ***Smoothing the spectrum*** - The low pass Savitzky-Golay filter was implemented on the spectrum to smooth it while maintaining the information concerning peak location and peak width, which are related to the physical observable.

Synthesized data was used in order to evaluate the different algorithms. Gaussian pulses rising from 0 to 8 volt were used to scan the MCA 's channels. Afterwards, the ADC results were analyzed off-line, calculating the average number of counts and the standard deviation for all the channels.

Results

The results of the different algorithms are summarized in table below

Algorithm	**Average**	**Standard deviation**	**Relative error**
Maximum peak sample	144.1	33.9	0.235
Average of 5 samples around peak	144.3	17.0	0.117
Butterworth filter	143.8	10.8	0.075
Average + Butterworth	144.6	11.6	0.080

Table 1. Performance comparison of different algorithms

As shown in Table 1, the Butterworth filter provides the best results. Unfortunately, the Butterworth filter can not be implemented directly using the FPGA. Instead, a simplified filter based on integer coefficients was implemented but the obtained results were not as good as we expected from the Butterworth filter. For this reason the Butterworth and related filters were rejected whereas the five samples averaging technique was adopted and implemented on the FPGA.

The Savitzky-Golay filter smoothed the data further on as shown in Fig. 3.

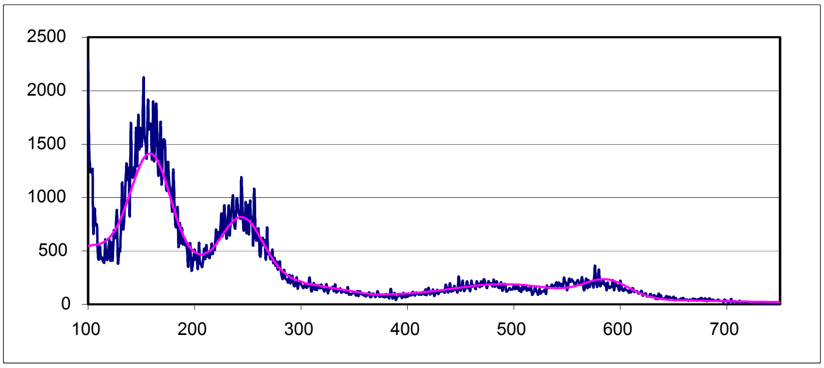

Fig 3. Smoothing the spectrum using Savitzky-Golay filter

By implementing both, the averaging and Savitzky-Golay filter, the instrument was calibrated and the cement samples were analyzed with satisfying results, as presented in Table 2.

Elements / Samples		Mg [%]	Al [%]	Si [%]	Ca [%]
Sample 1	Standard	1.37	3.01	14.69	42.72
	Measurement	1.31	2.79	15.07	42.56
	Difference	-0.06	-0.22	0.38	-0.16
Sample 2	Standard	1.30	2.31	11.24	44.97
	Measurement	1.28	2.27	11.10	44.74
	Difference	-0.02	-0.04	-0.14	-0.23
Sample 3	Standard	1.34	2.65	12.94	44.11
	Measurement	1.29	2.38	13.29	43.73
	Difference	-0.05	-0.27	0.35	-0.38

Table 2: Summary of Sample Analysis

Conclusions

In order to improve the performance of a cement analyzing system, several ideas were investigated to overcome the noisy ADC samples and the ADC DNL problem. Whereas the classical solution known as the "sliding scale" technique demands hardware modifications, the methods described in this work use the advantages of the FPGA flexibility and microprocessor computation power to achieve a high quality spectrum, based on software modification only.

References:

[1] E. Marcus, I. Elhanany, J. Nir, M. Ellenbogen, Y. Kadmon and D. Tirosh "*A Novel Architecture for Multichannel Analyzer*", The 20th Conference of the Nuclear Societies in Israel, (1999), p 159.

[2] I. Elhanany, S. Jacobi, M. Kahane, E. Marcus, D. Tirosh and D. Barak *"A New High-Throughput Real-Time Digital Pulse Height Analysis Technique for Radiation Spectroscopy*", Proceedings of the 7th Mediterranean Conference on Control and Automation (MED99), Haifa, Israel, (1999).