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Development of a PC based Multichannel Analyzer for Gamma-Ray Spectrometry

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ABSTRACT

A PC based multichannel analyzer was implemented using a PIC18F4550 microcontroller and two commercial analogue to digital converters. The developed multichannel analyzer has a maximum resolution of 13 bits and a maximum theoretical speed of 3840 counts per second. The microcontroller was used for interfacing the ADC modules to the PC through the serial port. The controlling of the ADC, reading out data and, analysis of data are carried out using the software package developed using Visual Basic. Other functionalities of the software include analysis of saved data, calculating integral and area of a selected region and saving a spectrum as a plot. Performance of the multichannel was compared with a commercial multichannel analyzer.

1. INTRODUCTION

A measurement of the differential pulse height spectrum from a radiation detector yields important information on the incident radiation. This type of measurements are widely used in fields such as Nuclear Physics, Radiation Physics and Medical Physics. A multichannel analyzer (MCA) is a device that can produce such spectra from signals generated by radiation detectors [1].

The early multichannel analyzers were very expensive devices based on arrays of memories, counters and dedicated CRT displays. However, with the advent of microcomputers, it has become possible to perform most of the processing of data and displaying of spectra in general purpose computers. This has made it possible to develop very cheap PC based multichannel analyzers [2].

This paper describes the development of a PC based multichannel analyzer with an interface to two commercial ADC modules designed for the NIM (Nuclear Instrument Module) standard. The PC to ADC interface was developed using a PIC18F4550 microcontroller. The motivation for the development of this instrument was a requirement that arose at the Department of Nuclear Science, University of Colombo for diagnosing problems in experimental setups based on commercial multichannel analyzers. The main requirement was communicating with the ADC modules and displaying the information in a PC for diagnosing problems of the ADC modules. However, the software was developed to extend the above capabilities for displaying the read out data in such a way that it could replace a standard multichannel analyzer.

The main outcome of this project was a low cost and high speed multichannel analyzer with user-friendly computer software. The interface module between the ADC and the PC is connected to the PC through the serial port and data are transmitted to the PC for storage, analysis and display. Although the PIC 18F4550 comes with a USB port, the

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Institute of Physics – Sri Lanka

serial port was used for simplifying the software interface. USB communication can be implemented by writing a suitable device driver for the PC.

2. ADC TO PC INTERFACE

The overall architecture of the multichannel analyzer is shown in Fig. 1.

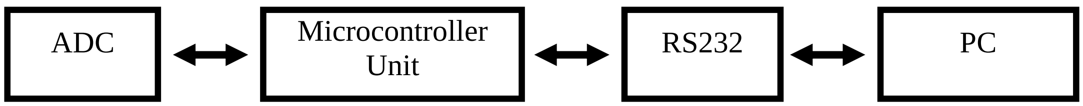

Fig. 1: Overall architecture of the multichannel analyzer

2.1 The ADC modules

The ORTEC 800 ADC [3] has an input range from 0 to +10 V and a conversion gains of 8K, 4K, 2K, 1K, 512, and 256 channels. The ADC processing time varies from 0.75 µs to 3.0 µs and depend on the conversion gain. The ADC is controlled by a 100 MHz crystal and work in Pulse Height Analysis (PHA) mode only.

The CANBERRA Model 8701 is a 100 MHz Wilkinson ADC with 8192 channels of resolution [4]. It has an input range from 0 to +10 V and conversion gains of 8192, 4096, 2048, 1024, 512, or 256 channels. The maximum conversion time varies from 4.1 µs to 83.5 µs depending on the conversion gain. The ADC is able to work in Pulse Height Analysis (PHA) mode or Sampling Voltage Analysis (SVA) mode.

2.2 ADC to PC data interface

In the ORTEC 800 module, a 36-pin Amphenol connector on rear panel provides gated binary buffered channel addresses and control signals to permit interfacing to external data storage devices. The signals are compatible with TTL logic requirements [3]. In the Canberra 8701 module, a 34-pin ribbon connector provides all the necessary signals for interfacing. [4].

For connecting these two ADC modules to the PIC18F4550, two separate cables were made. The ports A, B, C, D and E of the PIC microcontroller were used as I/O ports for this purpose and the pin assignments are shown in Fig. 2.

Pin No:	7	6	5	4	3	2	1	0
PORT A			DATA READY /READY*	BUSY /CDT*		COLLECT LED	ADC 12	ADC 11
PORT B					TRANS COM /ACEPT*	TX TROBE /ENDATA*	PHAA /ENC	ABORT /INB*
PORT C	RX	TX				ADC 10	ADC 9	ADC 8
PORT D	ADC 7	ADC 6	ADC 5	ADC 4	ADC 3	ADC 2	ADC 1	ADC 0
PORT E							ORTEC LED	CANBERRA LED

Fig. 2: Port arrangement of the PIC 18F4550

The communication between the microcontroller was through the serial port. A baud rate of 115200 with a 8-bit data word was used. Since the ADC word length was 13 bits, a single ADC reading could not be transmitted to the PC directly. Instead, each data word was broken into three 4-bit parts and each was transmitted with a serial number that runs from 1 to 3.

With a 20 MHz microcontroller clock and a baud rate of 115200, the theoretical maximum speed of the data readout was estimated to be 3840 counts per second. However, in the case of CANBERRA ADC, the conversion time varies from 4.1 µs to 83.1 µs depending on the gain, making the readout speed significantly lower.

3. SOFTWARE

PC Software for communicating with the PIC microcontroller and displaying data was developed using Visual Basic under Visual Studio 2010. Using this software, the user can control the ADC, readout data and display energy spectra. Calibration of the system can be carried out based on second, third or fourth order polynomials, by following the standard procedures.

A number of other functionalities including the analysis of saved data, selecting gain, calculating integral and area of a selected region and saving a spectrum as a plot are available in this software. Fig. 3 shows an energy spectrum as displayed by this software.

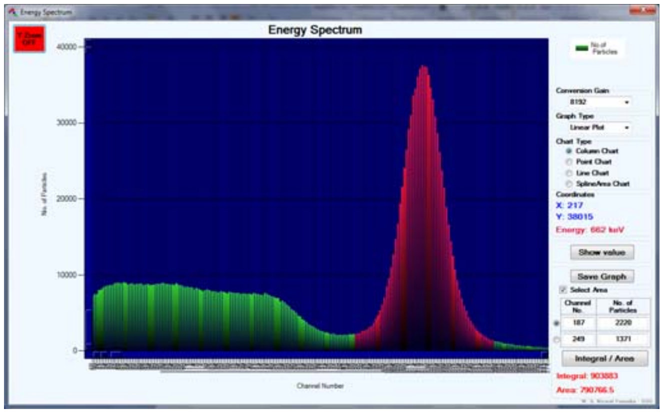

Figure 3. An Energy Spectrum window

4. CALIBRATION AND TESTING

Using point sources of Am241 and Co60, the developed multichannel analyzer was calibrated with each of the two ADC modules.

As a test of the system, two measurements of radiation from a soil sample were carried out using the two ADC modules. In addition, for comparison, the same soil sample was investigated with a CANBERRA series 35 Plus multichannel analyzer available at the Department of Nuclear Science, University of Colombo. The results of these measurements are shown in table 1. The standard energy values of the peaks shown were obtained from reference [5].

Table 1: Results from a soil sample

Soil sample	Gamma Energy (keV)			
	Standard values	CANBERRA SERIES 35 PLUS MCA	CANBERRA ADC	ORTEC ADC
K-40	1460.8	1481.1	1450.61	1469.0
Tl-208 (for Th-232)	583.02	600.6	568.07	580.15
	2614.48	2637.3	2674.36	2599.11
Bi-214 (for U-238)	609.31	631.4	610.72	592.85
	1764.49	1771.7	1778.69	1754.7

These measurements were carried out only for comparison purposes. The uncertainties of the peaks are usually calculated by measuring the width of the peaks. Since these widths mainly depend on the detector used and not on the system developed under this project, the uncertainties are not shown.

Proceedings of the Technical Sessions, 28 (2012) 31-36
Institute of Physics – Sri Lanka

In order to evaluate the speed of the multichannel analyzer (the number of particles read out per second), a set of radio active samples and the soil sample mentioned above were used. A comparison of the counting speed, based on counts taken during 1000 second periods with different radioactive sources are shown in table 2.

Table 2. Comparison of the speed of measurements

Source	**Counts per second**		
	CANBERRA SERIES 35 PLUS MCA	**CANBERRA ADC**	**ORTEC ADC**
Na-22	64.9	231.2	3428.7
Co-60	431.5	732.8	3513.8
Ba-133	2622.0	1932.3	3468.9
Cs-137	3148.4	3366.3	3470.8
Am-241	2694.6	2328.2	3514.1

Due to a limitation in the Series 35 Plus MCA, it was not possible to use the same threshold for all the three measurements. Number of counts obtained with the ORTEC ADC appear to be limited by the speed of the MCA while the lower values from the other two (with the possible exception of Cs-137) appear to be limited by the threshold. This comparison shows that the counting speed of our MCA is not inferior to that of the commercial ADC. It could even be somewhat superior to that. Also, it is important to note that the highest speed of 3514 counts per second observed here is quite close to the estimated theoretical limit of 3840 counts per second.

5. CONCLUSION

Development of a PC based low cost multichannel analyzer is presented in this paper. Hardware developed under this project was mainly an interface between the ADC modules and the PC. The remaining functionalities were implemented through software. Although the cost is low, it has been demonstrated that it has been possible to achieve the same level of performance as a commercial device. The ability to control the ADC modules through software provides the possibility of diagnosing problems – a feature not available in commercial systems.

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Proceedings of the Technical Sessions, 28 (2012) 31-36
Institute of Physics – Sri Lanka

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