Low Cost Gamma-Ray Acquisition/Analysis System

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A low cost gamma-ray acquisition and analysis system has been developed to work with an IBM-PC compatible microcomputer. The hardware is a card installed in the expansion slot of the microcomputer, interfacing it with a nuclear ADC. The acquisition is controlled by a memory resident software activated by interrupts. The analysis software has a user-friendly interface. It performs least squares fits of gaussian peak shape and background, energy vs channel data and spectra sum.

I. Introduction

The acquisition and analysis of gamma-ray spectra in nuclear physics have always been associated with the use of Multichannel Analyzers (MCA). In the last few years these instruments have incorporated microcomputers as a more or less independent tool, allowing powerfull analyzing capabilities.

We developed a low cost hardware to interface an IBM-PC compatible microcomputer with a nuclear ADC, thus forming a MCA system, and a software tool to control and display data aquisition. Gamma-ray spectra can be analyzed on-line with the same software.

II. System Hardware

The hardware is a printed circuit board which goes into the expansion slot of the microcomputer. The board (electric diagram shown in Fig. 1) consists of a peripheral parallel interface 8255 (PPI), a counter/timer 8253 (CT), and an address decoding logic. A set of jumpers is provided to select the I/O polarity of the ADC.

The address decoding logic assigns addresses to ports A, B, C and control register of the PPI and to the counters 0, 1 and 2 of the CT. This is done in the user reserved I/O address space of the microcomputer[1]. The ADC sends an interrupt signal (IRQ2) to the microcomputer, through the board, when a conversion is completed. The control software AQUI7 captures the ADC's datum (up to 13 bits) using the PPI ports A and B. AQUI7 enables the ADC to a new conversion sending a data accept signal through port PC0.

The three most significative bits of port B must be connected to ground or +Vcc, in accordance with the polarity of the ADC's data bus.

The bits 10, 11 and 12 can be disconnected from the PPI when using ADCs with less than 13 bits.

The counter/timer is used to temporize the acquisition. The internal counters 0 and 1 are programmed in mode 2 and counter 2 in mode 0. The time base is provided by the OSC signal of the microcomputer. The acquisition can be made in live or real time mode, according to switch SW1.

III. System Software

The system software is divided in two computer programs.

AQUI7 is a memory resident software written in assembly language. It provides the low level control and communications with the board.

A pre-defined sequence of timed acquisitions can be made with each spectrum being automatically stored in disk.

The microcomputer is free for other tasks during data acquisition.

REGULUS is written in high level language and assembly. It performs the tasks of data display and analysis. Its modular project allows modifications and upgrades in an easy way.

The human-machine interface (HMI) design is user centered with menus (novice users) and function keys (expert users), so all the functions can be easily chosen. Dialogue boxes are used to request input data. AQUI7 is linked with REGULUS which provides the HMI for the acquisition control.

In data display mode, the screen is divided in two main windows. The first one displays the spectrum with scales (vertical and horizontal) chosen by the user. In the second, the full spectrum is always displayed with a cursor indicating the center of the region displayed in the first window, so it is possible to see the detail and the full spectrum together (Fig. 2). The cursor keys allow the user to explore the entire spectrum at several different scales. The number of counts and the channel number at the cursor position are displayed. A vertical log scale is also avaliable.

The analysis mode allows a non-linear least-squares fit of a peak shape (gaussian) and background, through the gradient expansion algorithm (Marquardt)[2] to obtain precise peak positions and areas, FWHM and variances. The peaks (multiplets up to 12 components) to be fitted must be indicated through the cursor, and (optionally) the upper and lower limits of the region to be fitted. The continuous background is fitted by a polynomial function with degree up to 2, and can be chosen by a menu. No constraints on the fitting parameters are imposed.

The results of the fits are presented in numerical and graphical forms. The graphics are presented in two windows superposed to the data display, one with the experimental data and fitted curves, and the other with the residues, as in Fig. 3. Numerical results can be seen in another window, overlapping the graphics. All numerical results can be saved in disk for later use.

It is possible to make an energy calibration giving the energies of fitted peaks. The efective variance method[3] is used to account for the uncertainties in both energy and position variables. The calibration is made through a fit of three polynomial curves: linear, quadratic or cubic, chosen by the user.

Different spectra can be summed (channel to channel) to increase analysis capabilities.

The REGULUS allows spectra with Ortec or ASCII formats to be read and analyzed. It handles spectra constrained to 512, 1024, 2048, 4096 or 8192 channels.

IV. Software test

REGULUS fitting procedures have been tested according to Koskelo approach[4]. Several sets of ^{60}Co spectra were acquired with different amplifier gains so that the centroid of the 1332 keV peak in each spectrum is shifted to the rigth in increments around 0.5xFWHM (up to 3.0xFWHM) from a reference position (centroid of the 1332 keV peak for the first set). Each set has spectra with 1000, 2000, 5000, 10000, 25000 and 50000 nominal net peak areas for the 1332 keV peak. The fitted peak areas are considered “true areas”.

Two spectra from different sets are summed to produce a series of doublets with different peak area ratios and peak separations. These doublets were fitted and the peak area of each component compared with the "true area". We used the sum option of the REGULUS in this test.

Results obtained for 1:5 ratio (1332 keV of ^{60}Co) and about 1000 counts for the low energy peak are presented in Fig. 4. In this particular situation, good results can be obtained even for 1xFWHM peak separation. However, a complete analysis, considering the various peak size ratios and number of counts, shows that the lowest peak area is comparable with the "true area" within 2σ for separations above 2xFWHM, regardless of the peak size ratios. The greatest peak area is compatible within la with the "true area" even for 1xFWHM separation.

Therefore, the REGULUS capabilities to resolve doublets is comparable to the five softwares tested in reference [4]. The bump shown in the peak size ratio of the left hand peak arises from the poor fit of the low energy of the peaks. This problem can be minimized by modifying the peak shape model. Besides the tests reported in this work, REGULUS has been tested by several users in the later years in research laboratories[5−7]. Also, it was used in the Experimental Techniques on Nuclear Physics courses at Physics Institute of the São Paulo University. It is used with diferent ADC Wilkinson type: Ortec 800, Northern NS-623 and Canberra 8075; and constant time conversion type: Nuclear Data ND 582 and ND 583.

V. Conclusions

REGULUS was designed to be an easy-to-use system indicated for acquisition and analysis of gamma-ray spectra.

The printed circuit board is of straightforward construction with inexpensive componentes easily found in the market.

The results of the REGULUS test are compatible with those found in the literature. Thus, it can be used with confidence to quantify the two components of doublets when their peak separation is greater than 2xFWHM. The characteristics of the system, allied with the fit confidence, make REGULUS a useful tool for education and research.

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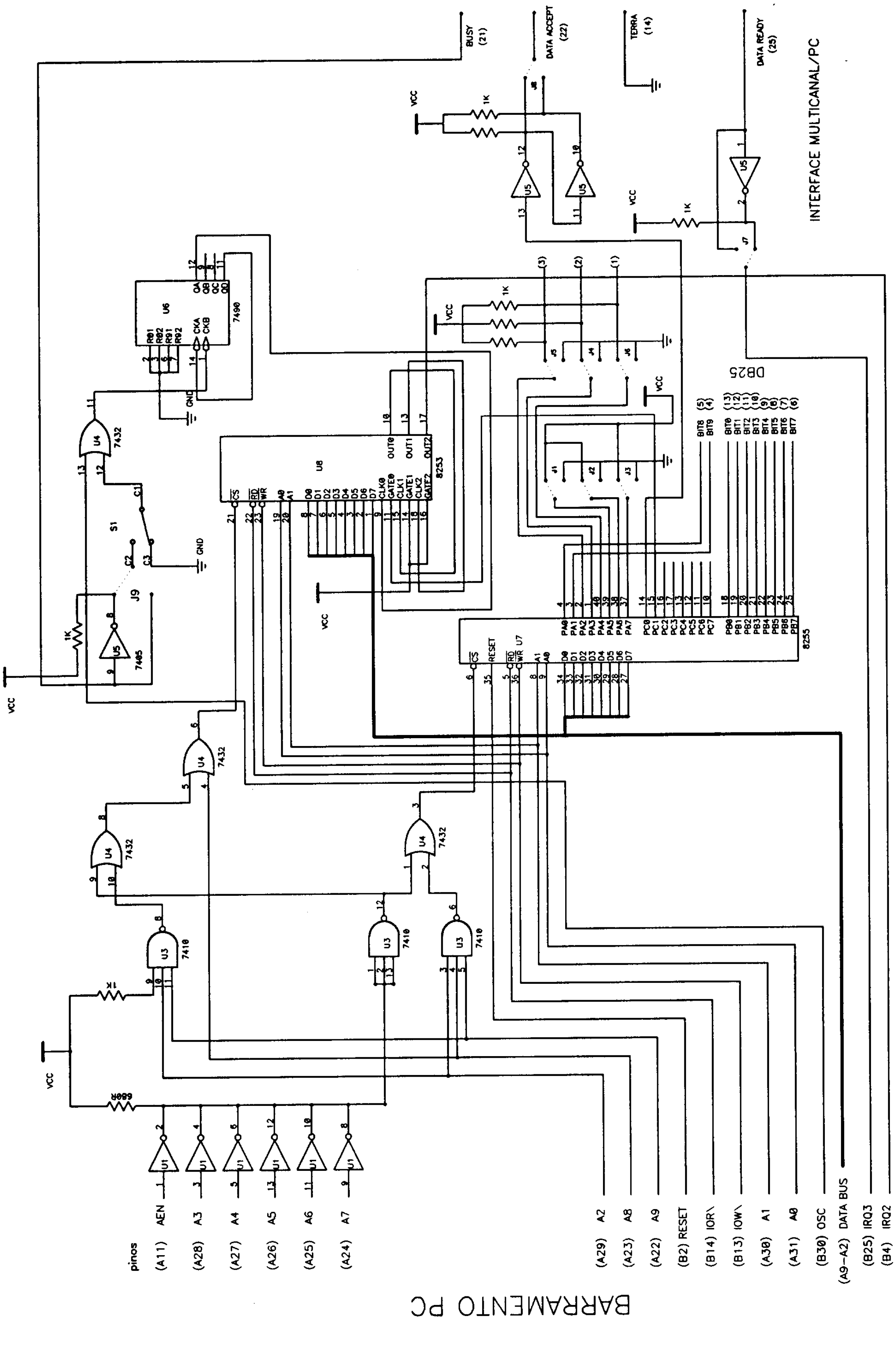

Figure 1: Electric diagram of the acquisition board.

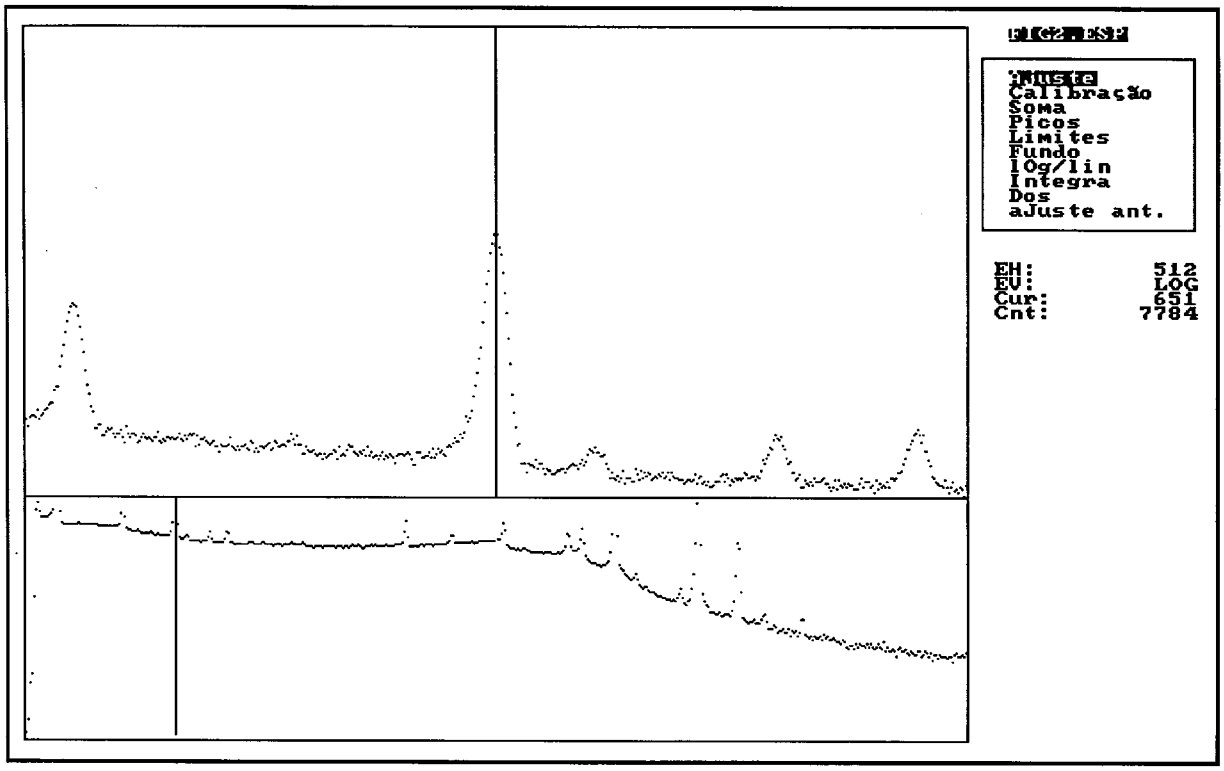

Figure 2: REGULUS data display showing the detail (upper) and full (lower) spectrum windows.

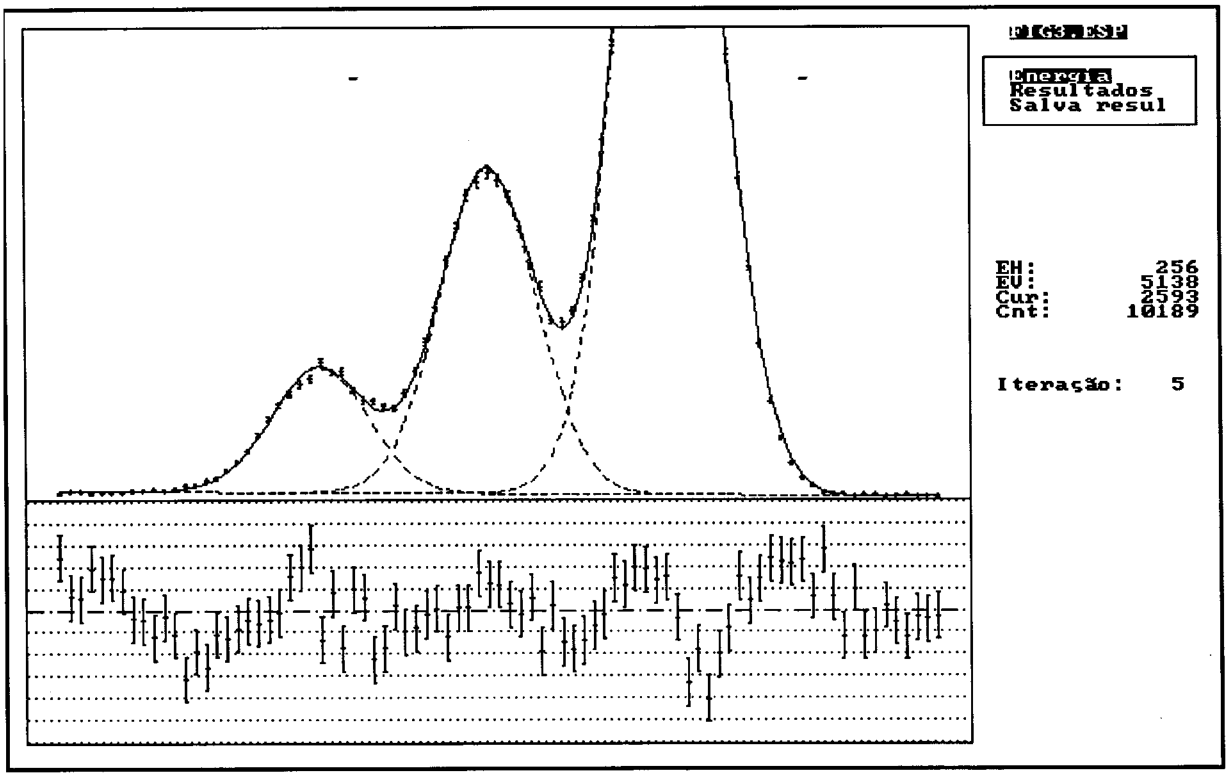

Figure 3: A gaussian triplet fit (upper window) and residues (lower window).

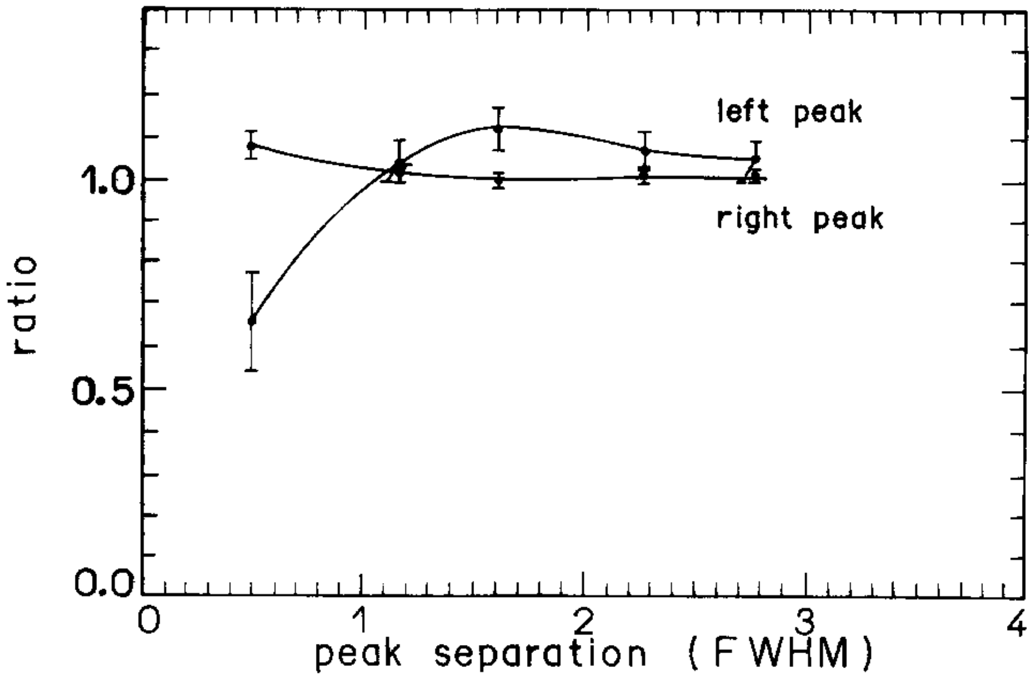

Figure 4: The ratio of the "true area" and the doublet areas as function of peak separation. The doublet ratio is 1:5 with 1000 counts in the lowest energy peak. All error are reported at 1σ.