STOCKHOLM UNIVERSITY
DEPARTMENT OF PHYSICS

A DATA ACQUISITION SYSTEM FOR PARALLEL ELECTRON ENERGY LOSS SPECTROSCOPY

C. ORSHOLM and S. CSILLAG

USIP Report 95-07  December 1995
STOCKHOLM UNIVERSITY
DEPARTMENT OF PHYSICS

A DATA ACQUISITION SYSTEM FOR PARALLEL ELECTRON ENERGY LOSS SPECTROSCOPY

C. ORSHOLM and S. CSILLAG

September 1995

Abstract
The data acquisition system used for parallel electron energy loss spectroscopy at Fysikum is replaced by a modern and more flexible system which easily can be modified or replaced in case of damage. The new system consists of a 16 bit A/D converter mounted on a PC card and a data acquisition program called Elproj version 1, written in the object oriented language C++ for Windows 3.1 or higher.

Introduction

When the electrons have passed the magnetic energy loss spectrometer, they hit a scintillating plate and light is emitted. A linear spectrum is created on the plate where the energy loss of the electrons decides how far from zero loss the light is emitted. The spatial axis is the energy loss and the light intensity is the number of electrons with a certain energy loss. This spectrum is to be recorded and stored by the data acquisition system.

The spectrum is detected by a photodiode array consisting of 512 light sensitive diodes placed in a row, each diode is 25 μm wide and 2.5 mm high. Before the light hits the array it is focused by two camera lenses between the scintillating plate and the photodiode array.

The signal from the photodiode array is read by an A/D-converter and recorded and stored by a computer program. These are the two parts which are replaced. One of the aims is to have a system which can be modified or easily replaced in case of new demands or failure. The data acquisition program must have a flexible structure in order to be easily understood by other programmers and allowing further implementations. The program is therefore written in C++ for Windows, a modern flexible language.

The A/D-card is a commercial product to which there exists software drivers supporting the program language C++. The card is constructed in a common way and can be replaced by other cards on the market in case of new demands.

The A/D-converter

The A/D-converter is mounted on an PC card manufactured by ComputerBoards Inc., which is called CIO-DAS 1402/16 and has a 16 bit 100 kHz A/D-converter, a timer with a clock and 3 counters. The card has both normal analogue inputs and differential inputs. The later can be of use when there is ground problems between the computer and the photodiode array.
The converter has several different ranges, both bipolar and unipolar, which allows many different signals. The timer-circuit is able to produce TTL signals from 3 different outputs. This is used to produce the TTL control signals needed for the amplification card of the photodiode array. That way, the read out of the array can be controlled entirely by the computer.

The A/D conversion is controlled by a gate signal which can be provided as an external input or as a signal from the timer circuit. The converter can be set to convert on either rising gate signal or falling gate signal. [1]

**The timer and TTL-signals**

By letting the A/D-card produce the required TTL-signals the data acquisition program is able to control the read out of the photodiode array. It is for example possible to control the integration time, or exposure time, of the array.

The amplification card of the photodiode array requires two TTL-signals. Primarily it needs a clock-signal which decides the rate at which the diodes are read out and placed on the video output. One clock-signal generates the result from one diode. Next clock-signal gives the result from the next diode in the row etc. The video output then becomes a sequential signal with the results from all the diodes in a sequence from number 1 first, followed by the others up till number 512. Secondly the amplification card needs a start-signal which tells when to restart the sequential read out of the array. Whenever a start-signal is received, the amplification card restarts and puts the result from diode number 1 on the video output again. Since the array consists of 512 diodes there should be at least 512 clock-signals between every start-signal in order to read out the whole array. The A/D-card is configured to send 1000 clock-signals between every start-signal. This means that we get 1000 different values per read out of the array where the 512 first is of interest.

The timer circuit on the card is an Intel 8254 counter circuit and a clock which can produce 1 or 10 MHz. The counter circuit consists of 3 different counters which can be configured in several different modes [2].

![Figure 1 The counters generate gate, clock and start signals.](image)

The counters are connected so that the signal from the clock enters counter 2 first. This counter divides the input with a programmable number allowing the computer to control the frequency of the output signal of counter 2.

The output signal from counter 2 then enters counter 3 which divides the input giving a non symmetrical output. This way the computer can control where on the video signal the A/D
conversion takes place. Since the amplification card sets a new diode to the video signal on every rising clock-signal but the A/D conversion is to take place on every falling gate signal there is a difference in time between output and conversion if the signal from counter 3 is used as both the gate signal and the clock signal. This difference in time is adjustable by changing the number in counter 3. The advantage is that stabilisation problems in the video signal is avoided this way.

Apart from being both gate and clock signal, the signal from counter 3 is sent to counter 1. This counter divides the input with 1000 generating a start signal at every 1000 clock signal.

Program development

The data acquisition program is called Elproj version 1 and is developed with Borland C++ for Windows. The structure of the code is chosen to be object oriented. This structure is easy to read by other programmers and it is possible to add new parts to the program without changing the rest of the program.

The Microsoft Windows environment

Borland provides a so called class-library together with the compiler, designed to manage all different objects in Windows, such as windows, buttons, menus etc. This class-library is called ObjectWindows Library OWL, and consists of several C++ classes helping to handle programs in Windows. These classes takes care of the complicated dialogue between the program and Windows, and provides an object oriented structure of Windows programming. It is possible to use the classes directly or to inherent them into new specialised classes to provide new functions to Window objects [3].

A/D card drivers

ComputerBoards Inc provides a package of driver routines designed to handle their different PC cards, including CIO-DAS 1402/16. The package is called Universal Library and consists of drivers to several program languages including C and C++. There are drivers for controlling A/D conversion, outputs and inputs, clock and counters etc. One powerful advantage of the package is that it fits all ComputerBoards products which makes it possible to change the A/D card without changing the program. [4]

Elproj takes advantage of the provided possibility of allowing the A/D conversion take place in the background. This way the output from the photodiode array is collected by the A/D
converter independent of what the computer does. Though the computer has to decide weather to keep the collected data or not.

The A/D-conversion and the signals to the photodiode array start as the program starts and continues until the program is terminated. Since the photodiode array works the same way during execution of the program, the stability of the signal during data collection is ensured.

The background process is an interrupt process in the computer, and the data collected is transferred by DMA, directly to memory.

**Data acquisition**

Since the A/D conversion continues all the time, memory would be full after a while. This is solved by letting the card write its data into a cyclic memory buffer. The program has to keep track of where the freshest data is stored in this buffer, and where the data from diode number 1 is stored. Once this is solved the program is able to record a spectrum from the array whenever it needs to.

The data buffer is chosen to be an integer \( n \) times the number of clock signals between two start signals. This way the buffer is able to contain \( n \) spectra at the same time, and the data from a certain diode will always be stored at the same \( n \) positions in the buffer. Once the program knows these positions it just has to ask the card where it is writing in the buffer right now, and then read the latest completely collected spectrum.

The program stops the A/D conversion and the clock signal, finds the position of where the A/D converter is to write next, and starts the A/D-conversion and clock signal simultaneously with a start signal. The position found in the buffer will then be the position of diode 1, and the rest of the positions of diode 1 in the buffer is straightforward to find.

When a spectrum is to be collected it just has to find out the writing position in the buffer (without stopping the conversion and photodiode array) and read out the latest completely stored spectrum.

**Elproj version 1**

Elproj version 1 is a data acquisition program running in Windows 3.1 or higher. The program is able to collect data from the photodiode array and display it visually on the screen as a two-dimensional graph with intensity as y-axis and diode number as x-axis. The spectra from the array can be showed in real-time mode, with a continuous updating of the screen, or just collected and stored in memory or on disk. In either case the spectrum can be examined in detail using zooming tools, or by comparing it to other spectra.

![Figure 3 Screen from the acquisition program](image)
Corrections
The program has some tools for correcting defects in the detector. The defects taken care of are statistical noise, integrated dark current, fixed pattern noise and differences in the response of the diodes, called non linearity defect.

The statistical noise is reduced by adding several spectra and taking an average spectra as the result. This way the actual signal (present in all spectra) is enhanced from the noise. The user is able to decide how many spectra to add.

The integrated dark current depends on both the temperature of the diodes and the integration time. Therefore it is essential that it is measured under the same conditions as the signal. This is done by darkening the array just before the signal is to be measured, and measure the signal from the dark array. This spectrum is then subtracted from the signal spectrum measured just after. The user can decide weather to subtract by a dark current spectrum (which then is measured) or not.

After subtraction of the dark signal there is a non-random variation between the diodes under uniform illumination. This is due to differences in the diode to diode sensitivity along the array. This non linear response is corrected by multiplying the dark signal subtracted spectrum by a linear reference mask. This mask is obtained by illuminate the array uniform and measure this spectrum, subtract with the dark signal and divide each diode value by the average value of all diodes. This correction works in some cases, but it seems as if the appearance of the mask changes with the intensity of the uniform illumination. The reason for this could be the camera lenses, but it has not yet been investigated.

Conclusions
The new data acquisition system is working and already in use at Fysikum. The A/D converter enables a better resolution than the previous 12 bit converter, and it is possible to control the read out of the photodiode array from the program, changing integration time etc. The system consists of commercial products which are replaceable in case of failure. The program provides a good user interface familiar to all Microsoft Windows users with zooming tools, corrections and compatibility with analyse programs used by the group.

References
[1] ComputerBoards, "CIO-DAS 1400"
[2] Intel, "8254 Counterchip"