

Report of Workshop on  
"Digital Electronics for Nuclear Structure Physics"

*March 2-3, 2001*

*Argonne National Laboratory*

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This report was written based on contributions by Kai Vetter, I-Yang Lee, Michael Maier, and David Radford. It was reviewed and approved by the GRETA Steering Committee.

## Executive summary

This document is a report of a workshop on digital signal processing (DSP) electronics for nuclear structure physics. The purpose of the described effort is to design and build a digital signal processing system for nuclear structure physics applications. The goal is to develop a state-of-the-art processing system which can meet different experimental requirements and enhance the capabilities compared to currently used analog systems in many aspects. To organize and optimize these efforts a workshop was held at the Argonne National Laboratory from 3/2/01 to 3/3/01 to discuss the different requirements of the nuclear structure physics community and to develop a framework for collaborations. About 45 scientists and engineers from universities as well as national laboratories attended this workshop reflecting the strong interest in such an effort in this community.

Presentations were made on the principle of DSP systems, their advantages over analog systems, and the status of current technology developments for nuclear physics applications. The focus of the contributions and the discussions was on the physics parameters such as energy, time, position, and particle identification for different detectors including semi-conductors, scintillators, and ionization chambers.

It was concluded that current efforts on developing and building one versatile DSP system can meet most of the requirements for this community. This system will consist of two boards, an ADC and a DSP board. The ADC board will contain the front end to condition and digitize waveform continuously using a 12-bit ADC with a sampling rate of 100MHz. Several on-board FPGAs will provide limited processing capability to extract relatively simple features such as energy, time, one-dimensional position, or particle identification for each input channel. This board will have the capability to generate and to accept complex triggers within a large time range. The DSP board is required to perform more CPU-intensive calculations such as signal decomposition or tracking calculations for the proposed gamma-ray tracking device. The separation of these two boards increases the flexibility but also minimizes signal distortions.

Currently, a 40-channel ADC board is being designed at LBNL and is expected to be available for testing by August 2001. It was agreed that an 8-channel version of this design will be made available to the community. They will be distributed to different labs for testing with different detectors. This effort requires 0.2 FTEs and \$20k in FY'01. To accommodate the different detector systems properly the front end of the ADC board has to be modified which requires \$50k. However, the main effort will be the development, implementation, and debugging of the software. We anticipate that 2 FTEs are required to implement software needed for all applications, 0.3FTEs each individual application and 3 FTEs for the signal decomposition and tracking software. In total, \$50k and 6.5 FTEs are required for FY'02.

A working group was formed to facilitate communication and to avoid duplication of efforts. In the immediate future it will coordinate the production, distribution, and testing of the 8-channel prototype boards.

# **Digital Electronics for Nuclear Structure Physics**

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# 1. Introduction

The recent advances in digital signals processing and its introduction into nuclear physics experiments allow us to realize more completely the full physics potential of detector systems. However, currently only a few modules are available, and their cost is higher than for analog electronics. Analog processing systems are well developed in experimental nuclear physics and a large variety of hardware modules is available. In addition, new developments in analog electronics are based on integrated circuits, which are optimized for specific applications. However, analog processing involves pulse shaping, which results in some of the information contained in the signal being lost.

This report summarizes the discussions and conclusions of a workshop on the requirements and capabilities of a digital signal processing (DSP) system for the low-energy nuclear physics community in the US. We conclude that current efforts on developing and building a versatile DSP system can meet most of the requirements for this community.

In the rest of this section we will briefly introduce the principle of a DSP system and discuss the advantages of a DSP over an analog system. Finally, we will discuss commercial systems which are already available or being built. In chapter 2 we will present the physics requirements and in chapter 3 the functional requirements. Chapter 4 discusses the schedule for the next two years, which will be organized by a electronics working group whose members and its scope are discussed in chapter 5.

## 1.1. Concept of a DSP system

The purpose of a DSP system is to convert an analog detector signal into a digital data stream as early as possible - generally after a preamplifier or a phototube -, ideally without degrading the quality of the signals. The input data are continuously sampled and stored in a circular buffer and can be retrieved after a trigger event. A field programmable gate array (FPGA) will handle the readout, trigger decisions, and simple signal processing. Dependent on the I/O and processing requirements the FPGAs can be replaced or augmented by DSPs for more complex calculations. These programmable units would extract the required physical quantities from the signal such as energy, time, position or particle identification. Complex triggers such as multiplicity or sum energy can be implemented digitally with a small latency. Data from this processing unit are transferred to a host computer or storage medium via a data and control bus.

Generally, such a DAQ system can be characterized by quantities such as number of parameters, number of channels, event rate, event length, trigger rate, allowable dead time, etc., which depend on the physics requirements. Accordingly, these systems will have different input characteristics (voltage/current input, AC/DC coupling), dynamic range, bandwidth, noise, and sampling rate as well as processing and data transfer capability.

Figure 1 shows a schematic lay out of a DSP system with a front end circuit containing

the shaper for the conditioning of the signal and the digitizer, the processing unit, the read out, and a unit to generate a trigger internally or to accept an external trigger.

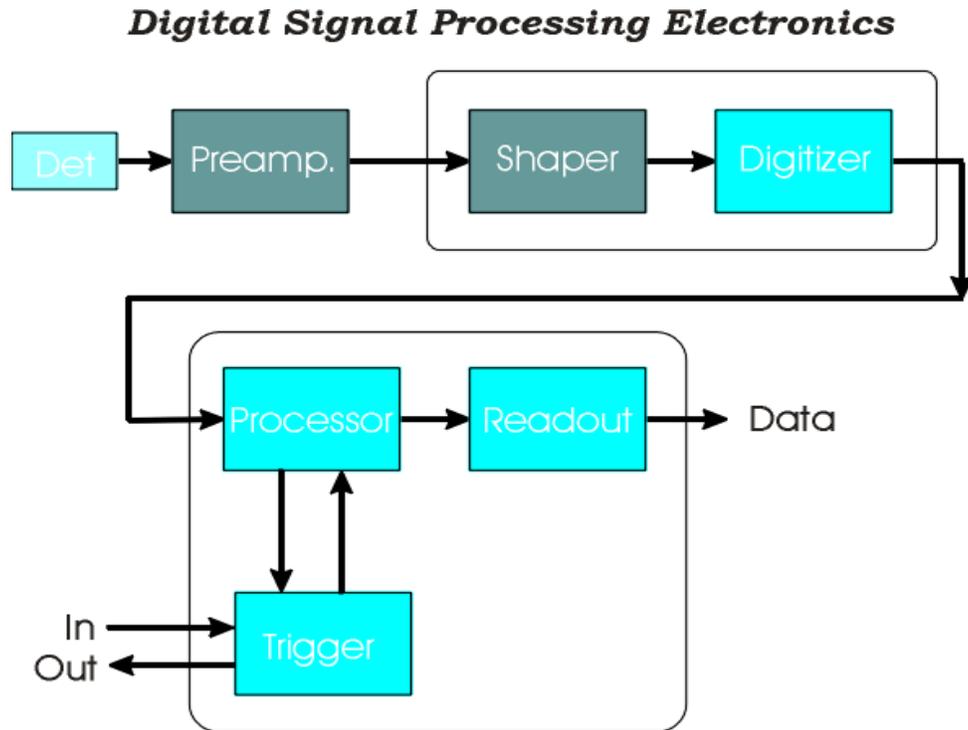


Figure 1: Schematic lay out of digital signal processing electronics for nuclear structure physics.

## 1.2. Advantages of a DSP system

While the analog and the digital processing have common goals, such as extracting information of interest with the highest quality possible and suppressing unwanted information, a digital signal processing system has many important advantages over analog systems. In the following we discuss the potential improvements with a DSP system in terms its versatility, performance, new capability, and channel density and reliability:

### Increased versatility:

In principle, many parameters which are extracted traditionally with analog electronics by using dedicated hardware modules can be done with digital processing and a variety of software. For example, energy (E), time (T), position (P), and particle identification (PID) of particles and photons in semi-conductor detectors can be determined by different algorithms implemented in the processing units with one DSP system. Furthermore, the possibility of configuring experiments by (re)loading software allows a degree of reproducibility which is difficult to accomplish otherwise.

Improved performance:

Optimum filtering and more complex algorithms can be implemented in software taking into account specific characteristics of the parameters for the different detector systems. Since the data are digitized early the loss in signal quality due to additional noise and shaping or pickup on signal lines is minimized. Signals can be transferred between boards or host computers using optical links without degradation. Another advantage is the implementation of complex trigger schemes, especially those that require more latency than is practical to realize in analog systems. Furthermore, one important characteristic feature of a DSP system is reduced, or even eliminated, dead time.

New capabilities:

Based on the fact that more complex calculations can be performed to analyze the measured pulse shapes, parameters can be determined which are otherwise not easily or not at all accessible with analog systems. For example, a gamma-ray tracking device requires very complex minimization and tracking calculations to be performed in real time which is impossible with an analog system. In addition, adaptive filtering algorithms are now possible increasing the allowable event rate in the detector. Furthermore, sampling at high speed with high amplitude resolution results in a large dynamic range preventing saturation effects which occur in analog amplifiers. The dynamic range for digitizers used in analog systems and in DSP systems are comparable; A measurement with a 100MHz (10ns) 11 bit ADC averaged over 1000 samples (=10us) will show an effective maximum dynamic range of 16 bit - neglecting imperfections, e.g. nonlinearities. A review of commercially available ADC components roughly agrees with this scaling law.

Higher channel density and increased reliability:

Since fewer components are required to build a DSP system, a higher channel density is possible. For example, as will be discussed later, it is envisioned to mount up to 64 detector channels on one VME board with the capability to determine the above mentioned quantities for a variety of detectors. Using fewer parts also results in an increased reliability.

### **1.3. Commercial DSP systems**

Within the last year, modules based on DSPs became available commercially, but their capabilities are still very limited, and they are very expensive. These available devices are based on high resolution but slow waveform digitizers; they are neither able to determine the time or position of the gamma-ray interaction (e.g. in solid state detectors), nor able to process many channels simultaneously.

The purpose of a newly designed DSP system is to overcome these shortcomings and to obtain energy, time as well as position information of photons or particles even at very high event rates for many channels (up to 64 on one board).

For more detail on available or planned commercial DSP systems we refer to the following web pages:

ORTEC: <http://www.ortec-online.com/dspec-plushtm>

Canberra: <http://www.canberra.com/literature/chronicle/oct99/insp2k.htm>

XIA: <http://www.xia.com>

SIS (former Struck): <http://www.struck.de/sis3300.htm>

Joerger: <http://www.joergerinc.com>

CAEN: <http://caen.it/nucleare/index.htm>

Currently, XIA provides the most advanced DSP system in terms of hardware and software. Its CAMAC module contains 4 ADC channels, one FPGA for processing and one DSP for histogramming as well as control. The ADCs have a resolution of 12 bits and a sampling frequency of 40 MHz. The main difference to other manufacturer is the provided software to enable the determination of energy and time. So far, these modules have been used for gamma-ray spectroscopy (mainly in Europe) and proton-decay spectroscopy (at ORNL).

## 2. Physics requirements

In this meeting we discussed the data acquisition needs of a variety of detector systems. In the following, physical quantities to be extracted and the requirements for a DSP design will be discussed for each type of detector. Table 1 summarizes requirements for the digitizer and the processing power.

### *Gamma-ray tracking detector:*

A gamma-ray tracking detector represents the most challenging detector system which is currently being discussed. The goal is to determine positions and energies of individual interactions of gamma rays in a segmented Ge detector. This is achieved by using net charge as well as transient charge signals in the segments to resolve individual interactions by decomposition calculations, which imply a minimization between a priori calculated and measured pulse shapes. Based on the positions and energies from all Ge detectors, tracking calculations are performed to identify and separate gamma rays which interact with the detector. The tracking algorithm consists of a cluster generation, evaluation, and classification.

The challenge is to perform these very CPU-intensive decomposition and tracking calculations in real time, even for highest event rates of more than 20kHz per detector. However, the fact that events of gamma rays are independent allows the distribution of different events to different processing units. We envision having DSP or CPU farms to tackle the two different tasks.

The goal of such a device is to determine the gamma-ray multiplicity, energy and time of the gamma rays as well as the three-dimensional position of the first two interactions. While the first interaction is useful for proper Doppler-correction, the two first interactions can be used to determine the linear polarization of a gamma ray.

Taking into account the dynamic rise time as well as response characteristics of state of the art preamplifiers a waveform digitizer with a sampling rate of 100MHz and an amplitude resolution of 12 bits is required. The total processing power was estimated to be  $10^{12}$  operations per second for such an instrument.

Semi-conductor detectors (Ge, Si or CdZnTe):

Standard Ge, Si or CdZnTe detectors, potentially one or two-dimensionally segmented, are used to extract energy, time, position of the first interaction as well as particle identification. All these parameters can be obtained by simple filter algorithms which can be implemented in FPGAs. The requirements are the same as for gamma-ray tracking detector thus a 100MHz and 12-bit digitizer appears well suited.

Slow scintillators:

Slow scintillators such as CsI(Tl) detectors are widely used for energy and time determination as well as particle identification. The 100MHz and 12-bit digitizer with a FPGA on board to perform the necessary calculations will satisfy the needs.

Fast Scintillators:

Fast scintillators such as liquid (NE213), plastic or BaF<sub>2</sub>, are also used for particle discrimination and energy and time determination. However, due to their fast risetime of a few nanoseconds or less, a sampling rate of 1GHz is required for the fast component of the measured signals. On the other hand, due to their poorer noise characteristics an amplitude resolution of 8 bits is sufficient.

Ionization chambers:

In Bragg curve as well as in multiple sampling ion chambers (MUSIC), the measured signal contains information about the energy and the particle type. Again a sampling rate of 100MHz and a resolution of 12bit will be sufficient.

<i>Application</i>	<i>ADC</i>	<i>Parameter</i>	<i>Processing</i>
$\gamma$ -ray tracking	100MHZ, 12bit	M $\gamma$ ,E,t,3D-pos., polar,etc.	High
Si, Ge, CdZnTe	100MHZ, 12bit	E,t,1D-pos,PID,etc.	Low
CsI(Tl), SISWICH	<100MHZ, 12bit	E,t,1D-pos,PID,etc	Low
n-det. (NE213), BaF	1GHZ, 8bit	E,t,PID,etc	Low
Bragg curve, MUSIC	100MHZ, 12bit	E,t,pileup,PID,etc	Medium

Table 1: Possible applications for the proposed digital signal processing electronics. The processing is classified in high for  $10^{12}$  operations per second (ops), medium for  $10^6$  ops, and low for  $10^3$  ops.

### 3. Functional requirements

In this chapter we will summarize the discussions on the functional requirements for different detector systems. We will discuss them in three areas: the front end and digitizer system, the trigger and readout, and data processing and programming.

#### 3.1. Front end and digitizer

##### Semi-conductor detectors (Ge, Si, CdZnTe) :

Since the risetime of the current state of the art preamplifiers is longer than 10nsec a sampling rate of 100MHz is sufficient. This sampling rate can also be seen to be sufficient by considering drift times of charge carriers in Ge and Si which are of the order of 10nsec/mm; these values are slower in Cd(Zn)Te. Thus 100MHz is adequate for detectors of thickness of 1mm or greater.

For a noise level of 5keV at the output of the preamplifier (as measured using the GRETA prototype detector) and an amplitude resolution of 12 bits, we expect an input range of 20MeV ( $5\text{keV} \times 4096$ ) assuming the noise is 1 LSB (least significant bit). Since the resolution improves as the square root of the sampling time, averaging over 10 $\mu$ sec would give a resolution "floor" of 17bit. In practice this is an upper limit, and the real resolution is probably more like 14 bit after averaging. To accommodate other ranges of signal amplitudes we will need gains of .2, .5, 1, 2, and 5. For the case of a pulse reset preamplifier measuring the reset step and the reset time will give a rough measure for the energy deposition of an interaction which saturated the preamplifier ( $\Delta E \sim \Delta Q = \text{reset current} \times \text{reset time} = C \times \Delta V$ ), for example an energy deposition between 20MeV and 50MeV.

##### Slow scintillators:

CsI(Tl) with photodiodes can be treated like a silicon detector. The light output of the scintillator has characteristic decay times in the  $\mu$ sec range. A SISWITCH arrangement where the silicon detector acts as a  $\Delta E$  detector can be treated the same way.

##### Fast scintillators:

Faster scintillators such as BaF<sub>2</sub>, plastic scintillators or liquid scintillators for neutrons require faster sampling. We propose to wait for the 1.25 GHz 8bit ADC-ICs to become available and use the same data processing architecture as for the 100MHz 12bit ADC.

For all these detectors one wants to separate the effects of different decay times from pileup. For neutron detectors this improves identification accuracy. For BaF<sub>2</sub> one can detect a second hit, e.g. from a Pion decay in the scintillator from the long scintillation time component of the BaF<sub>2</sub>.

##### Ionization chambers:

The pulse from Bragg curve detectors contains information about the total energy (total charge) and particle identification (maximum of the charge pulse). With a digital processor these quantities can easily be derived from the digitized pulse. Again a sampling rate of 100MHz and a resolution of 12bit is sufficient. For multiple sampling

ion chambers (MUSIC), digitizing at 100MHz and 12bit will reveal all the features of the signal that are used for particle identification.

### **3.2. Trigger and Readout**

The careful design of the trigger subsystem is crucial to acceptable performance over the range of experiments that will be performed with a data acquisition (DAQ) system. For example, flexibility in the types of trigger that can be generated or utilized, and in the timing of the trigger, determine how well the system will perform in conjunction with other detector types. The DSP system should be able to accommodate other systems both analog and digital. To integrate detectors utilizing analog electronics requires a selective combination trigger within a fixed time in order to avoid excessive dead time imposed by digitizing unwanted events. Likewise, the time taken to read out digitized events often limits the accepted event rate of a data acquisition system.

The trigger requirements of DSP DAQ systems, as they might be applied to various types of detectors, were discussed. The discussion included the type of information that might be required (e.g. multiplicity, low and high energy windows, hit patterns and pulse shape information); the means by which each module would pass its local trigger information out to other modules and/or a master trigger module for combination with other detector systems; the number of levels of triggering that might be implemented; and the minimum/maximum real-time latency for generation of a global trigger.

For all of the types of detectors considered, it was assumed that first-level triggering information would be generated by FPGAs. The foreseen design, with FPGAs dedicated to each input channel and another dedicated to the trigger, should be flexible and powerful enough to provide any of the required first-level trigger types.

For purely digital systems, the maximum acceptable trigger latency is determined solely by the depth of the ADC ring buffers, and can be increased sufficiently. For example, on the 40 channel DSP board which is currently being designed a 128kB memory depth allows to store 1ms worth of data for a sampling frequency of 100MHz. This enables to accept external triggers for up to 1ms. To provide a trigger to external devices we estimate a latency of the DSP system of about 100ns. Analog systems for auxiliary detectors do not in general provide for such a large range of latency. To allow use in conjunction with such systems, the DSP modules will have to generate a first level trigger in fast real time, typically within hundreds of nanoseconds to a few microseconds of the event. There was an apparent consensus at the meeting that this would require a global trigger box to combine the information from all of the DSP modules in deterministic real time. One possibility would be to use a "tree"-type structure, where DSP triggers are combined through one or more levels of branches; this would remove any preset limit on the number of modules that could be operated in any one system. Any such system, however, will also require the use of a fixed system-wide clock.

It was agreed by all present that a single level of trigger at the ADC/ring-buffer level would be adequate for all detectors, with a further level of filtering possible after more

extensive digital signal processing but before final readout.

By comparison with the extensive discussion of the trigger subsystem, not much time was spent on the readout. Clearly, the readout must allow sufficient throughput for all envisioned classes of experiments; this is not expected to be difficult as long as provision is made for parallel readout through high-speed links. For example, a sustained data rate of up to 100MB/s per board has to be handled, given by a gamma-ray tracking device and assuming no data filtering and compression on the ADC board is performed. As for the trigger, the read out and the event building process has to be able to handle data streams from different systems.

### **3.3. Data Processing & Programming**

The possibility to program a digital signal processing system implies many important advantages compared to an analog processing system. For example, it will be possible to perform a detailed pulse-shape analysis for an accurate position determination in a gamma-ray tracking detector; change experimental parameters without hardware modifications, and apply optimal filter or generally more complex digital processing algorithms to improve the quality of the data, or even extract new parameters from the instrument. However, to realize these advantages, efforts in algorithm development and programming are required.

In the following we briefly discuss the parameters to be obtained with the different instruments:

#### Energy:

In most cases the energy is related to the total charge produced in the detector. For the best achievable energy resolution an optimum filter has to be implemented which takes into account the response as well as the noise characteristics of the instrument. These filters are normally realized as finite impulse response (FIR) filters, which are standard implementations for FPGAs and DSPs.

#### Time:

To determine the time of the incoming particle (e.g. the start of the signal) FIR filters or procedures used in analog circuits (such as the constant-fraction method) can be implemented.

#### Particle identification:

Utilizing the fact that different types of particles generate different signal shapes in scintillators or semi-conductors, we can distinguish these particle types by pulse-shape analysis (e.g. by comparing ratios of signal amplitudes at different times). These methods can be implemented very easily in state-of-the-art FPGAs.

#### One-dimensional position:

One-dimensional position can be extracted either by determining time differences between two signals which is discussed above, or by analyzing the pulse shape. For

example, the time of the maximum current in a coaxial Ge detector is proportional to the radius of the first interaction, even if several interactions occur in this detector. The amplitude of a transient charge signal in a segmented Ge detector is proportional to the distance of the first interaction to the segment boundary. Using these two easily obtainable parameters it is possible to determine the position of the first interaction to better than 1cm in two independent dimensions. Also here, we envision implementing the algorithm in FPGAs.

Three-dimensional position resolution:

Three-dimensional position resolution, to resolve the location of individual interactions, is a crucial requirement for the proposed gamma-ray tracking array GRETA. The goal is to decompose the measured signal into the contributions of the individual interactions. The major challenge is to perform this very CPU-time intensive calculation in real time. Since the electrical coupling between the segments in one crystal is used, this processing has to be done locally for each crystal. We estimate that a processing power of about 5 Gflops is required. Currently, DSPs with about 1 Gflops computing power and boards with 4 of these DSPs mounted are available commercially. In the near future single DSPs with a computing power of up to 10 Gflops will be available. As an alternative, the required processing can be distributed over a larger array of processing units.

Tracking:

Tracking takes all the information on energies and positions of interaction points and convert them into number, energies and position of gamma rays. Here, we estimate a required processing power of about 300Gops. Although it is also a challenging task to perform these calculations in real time, the load can be distributed over a farm of computers where sequential events can be analyzed in parallel.

Except for the two latter computation-intensive applications, the other parameters discussed can be obtained from state-of-the-art FPGAs mounted on the ADC board. The more CPU-intensive calculations can be performed on higher-level processing boards. For example for a gamma-ray tracking detector, this DSP board would perform the decomposition calculations to determine the three-dimensional position and amplitudes of individual interactions in one detector. It could be connected to the ADC board via a fast optical link. The available connection is more than sufficient to satisfy the maximum data transfer rate between these two boards of about 100MB/s. The advantages of separating the ADC from the DSP system are the decoupling to avoid electrical interference from the high-speed digital signals, and a higher flexibility for different applications with different ADC or processing requirements.

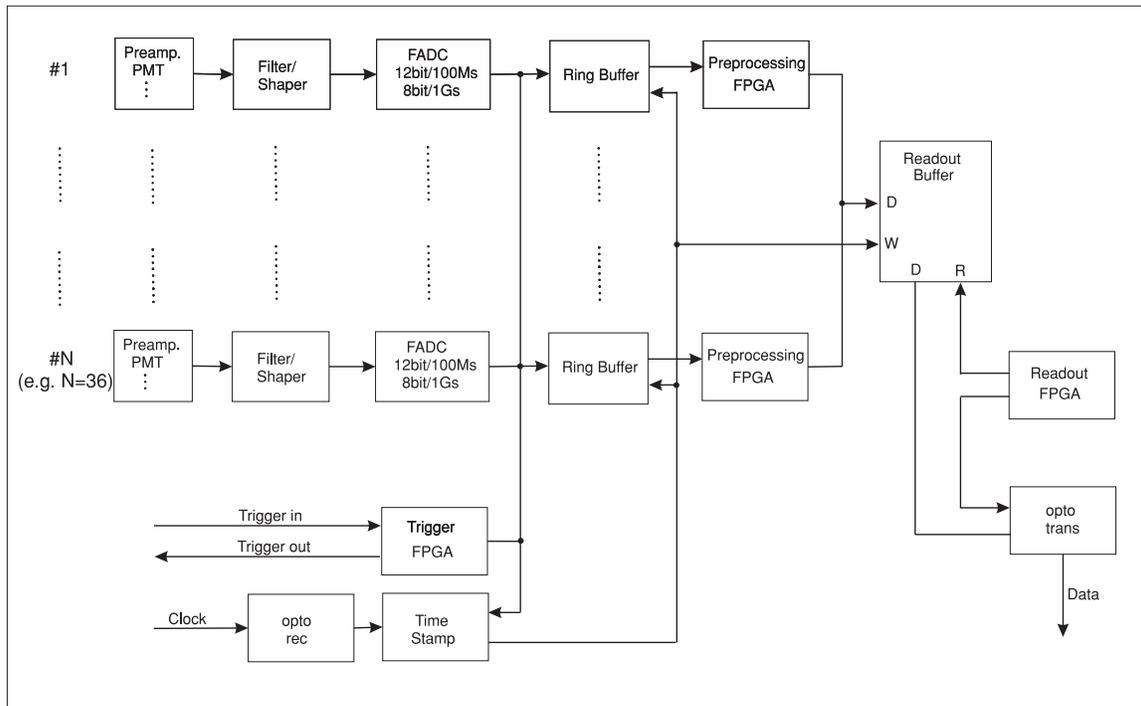
We expect these two types of boards to cover most of the applications in low-energy nuclear physics, including the basic, as well as the most challenging requirements. The currently available parts and fully equipped DSP boards will be able to meet both the computing requirements and the data rate requirements.

Based on the fact that most applications can be realized with a 100MHz and 12bit ADC

board with on board processing, the development should focus on the manufacture of this board including the testing and debugging as well as the implementation of the necessary algorithm to provide the requested parameters.

Figure 2 shows block diagrams of a multi-channel ADC and a DSP board. For the signal decomposition calculations of a gamma-ray tracking detector we envision to use 120 of such DSP boards, each with one input, which is connected to one ADC board for one crystal. Based on the processing power of currently available DSP or CPU systems we estimate that about 50 of these boards are needed for the tracking calculations.

### ADC/ Pre Processing Board



### Data Processing Board

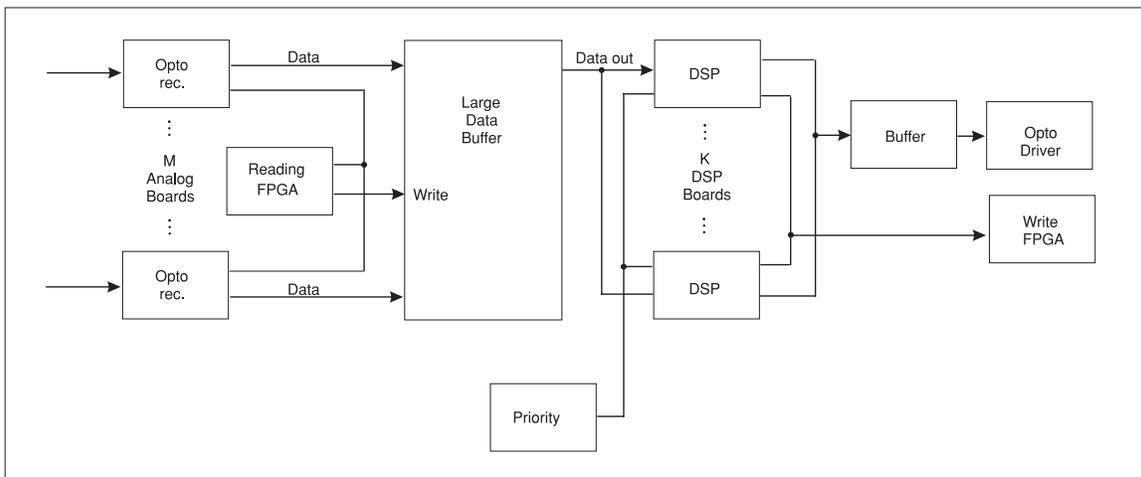


Figure 2: The ADC board (top) and the DSP processing board (bottom). Assumed are  $M$  ADC boards, each with  $N$  inputs (preamplifier or PMT signals) and  $K$  DSP processors to handle more extensive processing either of one or multiple ADC boards.

## 4. Development Plan for the Next Two Years

### 4.1. Goals and scope

The goal of this research and development is to design and build a prototype digital processing system for use with detectors in applications to low energy nuclear physics research. The system would consist of an analog front end, a digitizer and digital signal processors. The analog front end has to be tailored to each type of detector. Two types of ADC could satisfy all the needs of the community represented in the meeting; a 12-bit ADC with a sampling rate of 100 MHz, and an 8-bit ADC with a rate of 1 GHz. The former can satisfy about 90% of the needs, and only fast detectors such as BaF<sub>2</sub> require ADCs with 1 GHz sampling rate. The processing power on the ADC board is sufficient for most applications where only energy, time and particle identification information are needed. A second layer of commercially available processors can satisfy the additional processing power needed for the most stringent requirements of gamma-ray tracking detector arrays.

The scope of this development consists of

1) Design and fabricate analog front end

An analog pulse shaper/filter is required between the detector and the ADC. This circuit will provide appropriate gain and filtering to match the signal from a particular type of detector to the input of the ADC. The technology of design and production of these circuits is well established.

2) Design and fabricate ADC boards

Currently, a 12-bit 100 MHz ADC can be built using commercial components. A funded design effort is in progress at LBNL for such an ADC including on board processing capabilities, and a 40-channel prototype will be available by August 2001. It is envisioned that four 8-channel boards would be produced in September 2001 and distributed to the community for testing with other types of detector. Funding is needed for construction of these 8-channel boards. The 1 GHz ADC is not yet available commercially. We will postpone its implementation until such ADCs are available.

3) Select digital signal processor board

Currently available DSP boards can provide sufficient processing power and data transfer rate even for the most stringent requirements of gamma-ray tracking devices such as GRETA. We will evaluate these processors for their processing power, data transfer speed, expansion capability and ease of programming, and make a selection based on the results. The communication part of the ADC then will be designed to match the selected board in order to maximize the data transfer speed.

4) Develop processing programs

Digital processing shifts the job of signal processing from analog circuit to

numerical algorithms in computers. A number of programs need to be developed. Programs to transfer data, monitor and control the acquisition are common to all detector types. However for each type of detector, special programs are needed to process the pulse and extract information such as energy, time, particle identification and position.

#### 4.2. Costs and Manpower

The estimate for the electronics hardware is for design and production of prototype for each type of electronics. The estimate for software has two parts. The first part is for the basic acquisition control, determination of energy and time. The second part is for signal decomposition and tracking for gamma-ray tracking array.

ITEMS	Design/ Engineering (FTE)	Fabrication/ Purchasing (\$)
1.1 Front-end electronics (3 types)	0.6	6k
1.2 ADC		
1.2.1 40-ch board*	2.0*	20k*
1.2.2 8-ch board (4 each)	0.2	20k
1.3 Software		
1.3.1 common to all detectors	2.0	50k
1.3.2 specific to each type of detector	0.3/det.	
1.3.3 signal decomposition and tracking	3.0	

\* Currently an effort to develop a 40-channel ADC board for the GRETA cluster array is funded and is under way at LBNL.

#### 4.3. Schedule

The major milestones of the LBNL development effort of the ADC board are as follows.

- April 2001           complete circuit design
- May 2001            complete circuit board layout
- August 2001        complete circuit board production, and software development
- October 2001       complete phase one test
- December 2001     complete test with GRETA prototype

It is envisioned that four 8-channel boards could be produced by September 2001 and distributed to the community for testing with other types of detector. Specific front-end analog electronics and data processing programs have to be developed. The funding requirements in FY01 and FY02 are as follows.

ITEMS	FY01		FY02	
	Effort	Purchasing	Effort	Purchasing
	(FTE)	(\$)	(FTE)	(\$)
1.1 Front-end electronics (3 types)			0.6	6k
1.2 ADC				
1.2.1 40 ch-board (*)				
1.2.2 4x8 ch-board	0.2	20k		
1.3 Software				
1.3.1 common to all det.			2	50k
1.3.2 specific to det. (3 types)			0.9	
1.3.3 signals decomposition and tracking			3	
TOTAL	0.2	20k	6.5	56k

(\*) Efforts funded by LBNL LDRD

## 5. Working Group

The formation of a working group was discussed in the meeting and a group was formed soon after the meeting. The members of the Working Group are listed below. The Nuclear Structure Gamma-ray Tracking Steering Committee appointed David Radford as the chair of the Working Group.

Doug Cline (Rochester)  
Matt Devlin (LANL)  
Thomas Glasmacher (MSU)  
Jozsef Ludvig (LBNL)  
Augusto Macchiavelli (LBNL)  
Steve Naday (ANL)  
David Radford (ORNL), Chair  
Demetrios Sarantites (Wash. U.)  
Dariusz Seweryniak (ANL)  
Robert Varner (ORNL)  
Kai Vetter (LBNL)  
John Weizeorick (ANL)

This group will follow the advance of digital electronics and facilitate the communication among the participants. The goal is to avoid duplication of effort and to maximize the benefit of current and future development projects through collaboration and sharing of technology.

The immediate job for this group is to coordinate the community efforts in production, distribution and testing the 8-channel prototype boards. This work will involve the design and fabrication of the frond-end electronics, programming of the data processing algorithms, and development of the interface to computers. This group will function through regular phone conferences and workshops.

## Appendix A

### Meeting on "Digital Electronics for Nuclear Structure Physics"

March 2-3, 2001  
Building 203 Auditorium  
Argonne National Laboratory  
Argonne, Illinois

#### AGENDA

##### March 2, 2001

###### **7:00 p.m.**

Welcome/Goals of Meeting	<i>Kim Lister -- 15 min.</i>
Summary of Physics Requirements	<i>I-Yang Lee -- 20 min.</i>
Overview: Comparison of Analog and Digital Processing	<i>Michael Maier -- 20 min.</i>
Examples of Existing System	
LBNL	<i>Jozsef Ludvig -- 15 min.</i>
Washington University	<i>Lee Sobotka -- 15 min.</i>
ORNL	<i>Krzysztof Rykaczewski -- 15 min.</i>
ANL	<i>Steve Naday -- 15 min.</i>

##### March 3, 2001

###### **9:00 a.m.**

Discussion of Functional Requirements	
Front End and Digitizer Discussion Convener	<i>Thomas Glasmacher -- 60 min.</i>
Trigger and Readout Discussion Convener	<i>David Radford -- 60 min.</i>

###### **12:30 p.m.** LUNCH

###### **1:30 p.m.**

Discussion of Functional Requirements (cont'd.)	
Data Processing and Programming Discussion Convener	<i>Kai Vetter -- 60 min.</i>
Scope, Schedule, and Cost for Development	<i>Doug Cline -- 30 min.</i>
Conclusion/Forming of Working Groups/Plan for Proposal	<i>I-Yang Lee -- 30 min.</i>

## Appendix B

## List of participants

	<b><u>Name</u></b>	<b><u>Affiliation</u></b>
1	Daniel Bazin	Michigan State University
2	Mike Carpenter	Argonne National Laboratory
3	Bob Charity	Washington University
4	Douglas Cline	University of Rochester
5	Patrick Delurgio	Argonne National Laboratory (ECT)
6	Romualdo de Souza	Indiana University
7	Matthew Devlin	Los Alamos National Laboratory
8	John Elson	Washington University
9	Thomas Glasmacher	Michigan State University
10	Robert Haight	Los Alamos National Laboratory
11	Jerry Hutchins	Florida State University
12	Robert Janssens	Argonne National Laboratory
13	David Jenkins	Argonne National Laboratory
14	Teng Lek Khoo	Argonne National Laboratory
15	Filip Kondev	Argonne National Laboratory
16	Torben Lauritsen	Argonne National Laboratory
17	I. Yang Lee	Lawrence Berkeley Nat. Lab.
18	Kim Lister	Argonne National Laboratory
19	Jozsef Ludvig	Lawrence Berkeley National Laboratory
20	Michael Maier	Lawrence Berkeley National Laboratory
21	Michael Momayezi	X-Ray Instrumentation Assoc.
22	Will Mueller	Michigan State University
23	Steven Naday	Argonne National Laboratory (ECT)
24	Bruce Nardi	Argonne National Laboratory
25	John O'Donnell	Los Alamos National Laboratory
	Daniel Pedtke	Michigan State University
26		
27	David Radford	Oak Ridge National Laboratory
28	Krzysztof Rykaczewski	Oak Ridge National Laboratory
29	Pat Sangsingkeow	PerkinElmer Instruments
30	Demetrios Sarantites	Washington University
31	Wojciech Skulski	University of Rochester
32	Lee Sobotka	Washington University
33	C. Ray Sporleder	Indiana University
34	Richard Todd	RIS Corporation
35	Jan Toke	University of Rochester
36	Andrew Vander Molen	Michigan State University
37	Robert Varner	Oak Ridge National Laboratory
38	Kai Vetter	Lawrence Berkeley National Laboratory

39	John Weizeorick	Argonne National Laboratory (ECT)
40	Phil Wilt	Argonne National Laboratory
41	Andrea Woehr	Argonne National Laboratory
42	Darek Seweryniak	Argonne National Laboratory