

Did You Know?

GaGe RazorMax Express Digitizer/Oscilloscope

An Efficient & Cost-Effective Tool for
High-Energy Physics Particle Counting Applications



PC-based digitizer and digital signal processing software combine to perform multichannel analyzer (MCA) and modular instrumentation functions at lower cost.

Introduction

An important category of experimental physics is nuclear and particle physics, a near synonym for high-energy physics. A broad range of experiments in this domain are classed as scattering experiments in which an incident particle hits a target and the resulting scattered particles are studied. Scattering processes can involve the creation or annihilation of particles.

The modern approach to studying scattered particles is to employ particle detectors, devices that detect individual particles impinging upon them.

This paper provides an overview of typical instruments used for gathering data in particle counting applications. It then describes how the GaGe RazorMax Express CompuScope digitizer/oscilloscope can be used to create and store the resulting data. The instrument's combination of high-speed data acquisition and signal processing offers an efficient, cost-effective approach for conducting particle experiments.

Gathering The Data:

In today's particle-counting applications, users commonly employ photomultiplier tubes (PMTs) and semiconductor detectors. This is an essential first step in particle experiments for gathering the data that will be analyzed.

As shown in Figure 1, PMTs are sensitive detectors of light photons that impinge upon their photocathode. When detecting photons, a scintillator material is often placed before a PMT. The scintillator converts sub-atomic particles into light photons that are then detected by the PMT. The PMT can therefore serve as a detector for a wide array of particles.

In many applications, semiconductor detectors (Figure 3) are often used in place of a PMT. Like PMTs, these detectors produce an electrical pulse when hit by a particle. Pulses may have a duration of a few nanoseconds to a few microseconds and have a pulse amplitude that is proportional to the particle's incident energy.

Analyzing The Data:

For PMTs and semiconductor detectors that provide energy proportionate output pulses, the workhorse instrument is the multichannel analyzer, or MCA. In pulse height analysis (PHA) mode, the MCA presents a histogram display (Figure 4) of the number of particles detected against pulse amplitude, which is proportional to particle energy. In Figure 4, the display shows a histogram of the number of pulses (counts), like those of Figure 2, that have been detected at a given amplitude, plotted as "Channel Number." The diagram shows a peak at just below Channel 1500 and an increasing count at low channels, which corresponds to background noise.

In addition to complex processing like coincidence detection, particle experiments intrinsically require flexible and reconfigurable instrumentation as compared with other applications. This requirement from nuclear and particle physics provided the initial motivation for modular instrumentation, which refers to instruments that fit into a platform that provides common electrical power, compactness and easy interconnection.

An early standardized modular platform was the nuclear instrumentation module (NIM) chassis, which provided common AC and DC power for NIM instrument modules. Later platform standards, such as CAMAC and VXI, incorporated digital communication between instrument modules and a host computer that allowed for instrument configuration, control and data recovery. Today's PC equipped with PCI Express (PCIe) slots for modular device cards is descended from modular platforms like CAMAC.



Fig. 1. Examples of photo-multiplier tubes, or PMTs (Photo courtesy of Hamamatsu).

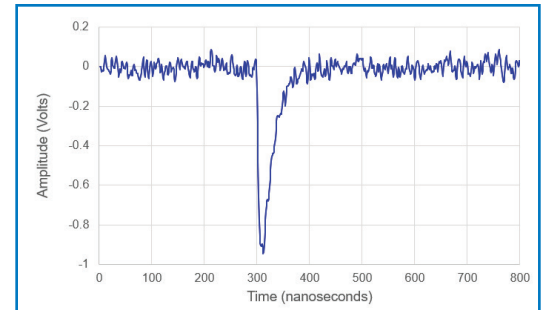


Fig. 2. The graph depicts a typical negative-polarity sub-microsecond pulse that is output by a PMT.



Fig. 3. Example of a semiconductor detector (Photo courtesy of Leybold.)

GaGe RazorMax Express CompuScope: Advantages

The GaGe RazorMax Express CompuScope digitizer/oscilloscope (Figure 5) can provide the same functions both as an MCA and as traditional modular instrumentation -- but at a lower cost. Any conceivable particle processing algorithm may be executed as digital signal processing (DSP) on digital waveform data acquired by the instrument's CompuScope.



Fig. 5. Vitrek's GaGe RazorMax Express CompuScope 161G4

One clear advantage of the GaGe RazorMax Express CompuScope digitizer/oscilloscope -- as compared with an MCA or traditional instrument module -- is that the digitizer can retain all raw particle pulse waveforms. These data might be used, for example, to detect and eliminate multi-pulse events.

The RazorMax Express also provides a unique advantage for particle experiments, which is their ability to perform "Complex Triggering." In this mode, trigger events from all channels are Boolean "OR"ed together to generate the final trigger event. This way, triggering occurs whether a particle enters any one of several detectors connected to the CompuScope. This scheme may be extended to multiple CompuScope boards by interconnecting their Trigger Out and Trigger In connections.

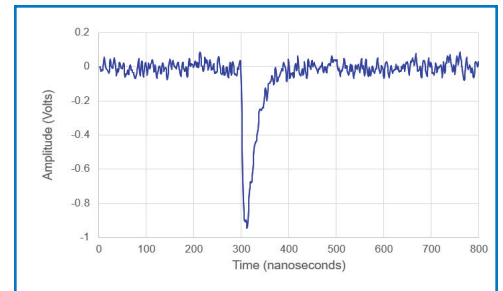


Fig. 4. Diagram of a typical display output from a multichannel analyzer.

The RazorMax Express may be operated using the flagship GaGeScope software, which provides an oscilloscope-like interface from which the user may operate their CompuScope without writing a line of computer code. However, GaGeScope provides neither the particle counting display and analysis nor the control of other devices required for a complete particle counting system. Instead, GaGeScope provides powerful Software Development Kits (SDKs) that allow the user to write their own software applications in C, LabVIEW, MATLAB, Python or virtually any other language from the Windows or Linux environment.

Application Example: Digitizer Operation in a Nuclear and Particle System

As an example, consider a user with four PMTs and associated conditioning electronics. The PMTs produce broad pulses about 1 microsecond wide but require the system to operate with faster detectors. The system will be used for multiple experiments with different configurations and count rates.

The user selected the GaGe RazorMax Express CompuScope 161G4. Its four input channels will digitize the four PMT signals. More RazorMax Express cards can be added for higher channel counts. An incident particle hitting a target creates particles entering four detectors positioned at specific angles. The four channels of a RazorMax Express card in the host PC acquire these pulses. Data from the four channels are streamed to a GPU card for rapid processing and reduction, then transferred to a custom software application using a Gage Software Development Kit sample program.

At 1000 MS/s, the RazorMax Express acquires one sample every nanosecond, accommodating pulse widths as short as 10 nanoseconds. The 16-bit vertical ADC resolution on the RazorMax allows operation in "Multiple Record Mode," acquiring short ~1 microsecond records. An interval of less than 1 microsecond is required to re-arm the RazorMax Express, allowing count rates up to 500 kHz.

In "Streaming Mode," data are transferred directly to the PCIe bus and streamed onto PC RAM memory. When continuously sampling on all four channels, the RazorMax Express creates a data stream of 8 GB/s, equal to the theoretical maximum Gen 3 X8 PCIe bus. In practice, the user will acquire no more than half the time, leading to a maximum 4 GB/s data rate.

Waveform data may be streamed to a fast drive for later analysis or to a DSP algorithm on the host PC or a GPU card. Algorithms can reduce raw waveform data in real-time to the desired results. The user can monitor and modify the DSP until achieving the desired results.

In many applications, triggers are generated at known intervals. "Time Stamp" values are crucial in particle physics experiments for calculating inter-particle detection intervals or average count rates. Time Stamps provide the arrival time of each particle pulse with nanosecond accuracy. They are appended to the end of each Multiple Record waveform within the data stream. The counter frequency can be disciplined with an external 10 MHz reference frequency if absolute timing is required.

Conclusion

The Gage RazorMax Express CompuScope digitizer/oscilloscope, combined with its powerful streaming software and triggering capability, allows the user to construct a low-cost measurement system for various nuclear and particle experiments.

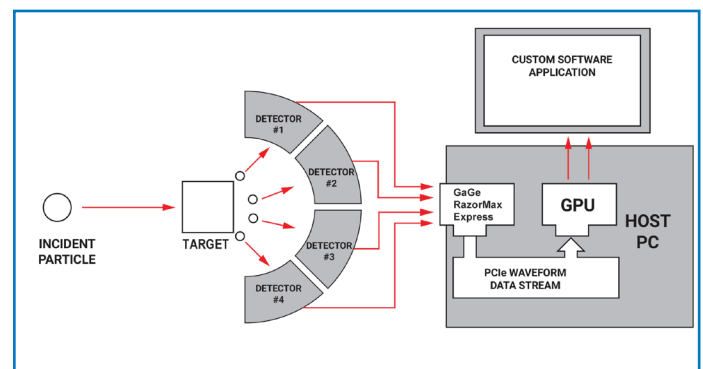


Fig. 6. Atomic particle counting system uses a GaGe RazorMax Express to acquire the detector pulses.