An Innovative, portable MCA based on Digital Signal Processing

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Abstract

Digital Signal Processing is being applied more and more to measurements in the field of nuclear spectroscopy. In all applications it offers greater stability, improved resolution and greater throughput at high count rates. All of these improve the quality of the spectrum and the analysis results. Recently, this technology has been incorporated in portable instruments. A new portable instrument will be described which offers all the digital benefits of DSP and adds features for additional functionality: a local display and keypad, significantly reducing the need for a PC in many field applications and an associated "intelligent" HPGe detector system, providing overall system state of health and allowing for the authentication of the entire system and its data. Performance data using a Safeguards-type HPGe detector are presented.

Introduction

The first, mains-powered, fully integrated high-resolution gamma-ray spectrometer (DSPEC) was introduced commercially several years ago. It has been used extensively in "difficult" measurement situations such as those encountered in nuclear safeguards and non-destructive assay[1].

For portable spectroscopy applications the LANL-developed Davidson PMCA[2] with on-board cassette tape storage, local display and limited "smart" capabilities has been the instrument of choice for safeguards inspectors across the world for routine measurements such as uranium enrichment.

The recent-generation of small portable MCAs, having no on-board bulk storage, display, keypad or computing power are "blind peripherals," and have required the use of an associated small computer. Whereas this approach is perfectly acceptable in a laboratory situation, where a desk top computer can provide excellent display, storage and analysis capabilities at low cost, in a portable instrument, the necessity to always carry a computer can be a strong disadvantage.

The new instrument reported here, with the trade-name digiDART™ is being produced by PerkinElmer Instruments (ORTEC). It combines the high performance attributes of the digital signal processing in a small, battery-operated package. For the first time since the days of the PMCA, the instrument includes an on-board display and the ability to store multiple spectra without the need for an accompanying PC. In addition, digiDART introduces new "SMART-1" HPGe detector technology, which can monitor the system "state of health" and provide authentication of spectral data.

Circuit Description

The digiDART hardware is shown schematically in Figure 1. The high voltage supply and detector monitoring are provided in a separate detector interface module (DIM). Following the front-end amplifier, a 14-bit, 10 MHz flash ADC samples the incoming pulse stream and converts each pulse into a string of digital numbers. This is then filtered directly by a proprietary digital filter algorithm, implemented in a field-programmable gate array

(FPGA). This also provides the functions of digital baseline restorer, fine gain, peak qualification, conversion gain, digital upper and lower discriminators, and spectrum stabilization. System control, keypad communications, spectral display and control of USB and/or RS232 communication is provided by the microprocessor. The microprocessor also controls the detector high voltage and provides the detector monitoring function. The battery-backed histogram memory provides up to 16000 channels of non-volatile data storage with optional 32000 channels. A flash memory provides for non-volatile storage of multiple spectra. Over 600 512-channel spectra may be stored. A digital version of the Gedcke-Hale live-time clock is implemented.

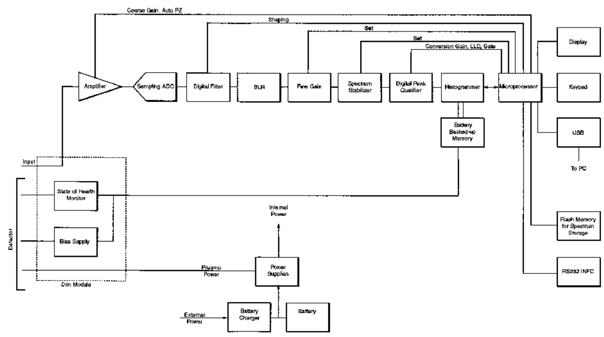

Figure 1 Portable MCA Schematic Block Diagram

The digital trapezoidal filter provides 99 risetime and 16 flat top choices in the ranges 0.8 µS to 20 µS and 0.5 µS to 2 µS respectively. This wider range of choices allows precise optimization of detector settings. A digital Automatic Pole Zero circuit[3] is provided, along with an optimize function which automatically optimizes the flat top tilt as well as Pole Zero across the range of rise time/flat top combinations.

Battery and Power Management

The instrument is powered by a single Sony NP-F960 camcorder battery, which will operate for up to 12 hours including supplying the detector power. The battery management circuitry is built into the instrument. Any 12V DC external supply will trickle charge the battery and operate the instrument. The battery may be replaced without loss of spectral data and the instrument restarted in seconds, to extend the operation beyond 12 hours. This single battery is more reliable and weighs less than the two battery "hot swap" design, where two batteries are attached but only one is in use at a time.

Physical

The instrument is packaged in an impact-resistant, ABS plastic enclosure, with rubberized overmolding, as shown in Figure 2. The outside overmold is a shock-absorbing, easy grip, stay clean coating. The display and sealed membrane keypad are recessed to protect them if the instrument is dropped. The easy-to-grip enclosure will fit in a box 20 cm x 12.7 cm x 7.7 cm and the weight including battery is <850 gm.

Figure 2 The portable MCA in hand-held use

HPGe Detector Support

SMART-1 technology improves the integrity of data and the chain of custody integrity as well as overall detector management practice. A SMART-1 detector is "intelligent." It is capable of monitoring and reporting back "state of health" (SOH) information. Moreover, it can be queried for its own identification serial number[4] and can have authentication codes written to it and later read from it to ensure authenticity of data. Because digiDART is part of the *CONNECTIONS*™ architecture, these operations may be carried out remotely over a network, which is of interest for unattended monitoring applications. During data acquisition, the SMART-1 detector monitors all of its own "vital functions;" preamplifier supply voltages, detector temperature, high voltage, overload state, HV shutdown state, serial number, and authentication code. Should any of the monitored functions fall outside a specified range of values (even if they subsequently return to normal), the condition is registered. At the end of the acquisition, the digiDART checks the SOH and will display a warning message. The SOH status is saved with the spectral data for QA purposes. User-developed packages may query SOH register in the digiDART for QA purposes.

At the start of the acquisition, the SMART-1 detector is queried for its serial number. A random number (authentication code) is written to the SMART-1 detector by the digiDART. At the end of the acquisition, both numbers are read from the SMART-1 detector and compared to the original values. An exact match assures data integrity.

A separate HV module, known as a DIM (detector interface module), is available for support of "non-smart" detectors.

Display and Built-in Analysis functions

The 240 x 160 pixel backlit LCD (Figure 3) provides live spectral display, status information and analysis results. It features full display, display of multiple ROIs and Zoom modes.

A Status line provides parameter display; with the user able to choose any two from: cursor energy, location, live time, live time remaining, real time remaining, battery life remaining, Count rate, Count rate in ROI, or counts. A real time Peak Information function reports centroid, FWHM, Net and Gross area for the ROI where the cursor is positioned.

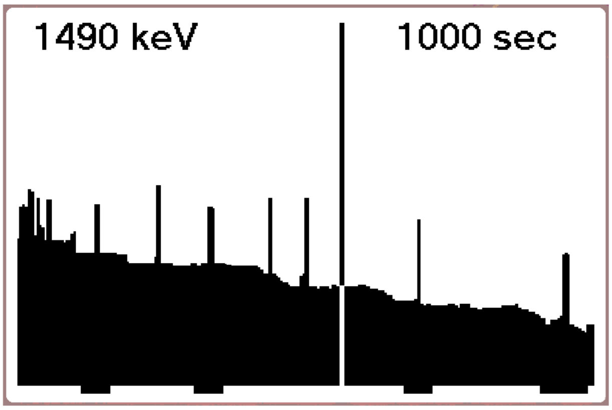

Figure 3 The portable MCA spectral display

A two-point energy calibration of channel and FWHM can be done at any time from the keypad. The user can define from 1 to 9 regions for the Nuclide activity display. The activity with uncertainty is calculated and reported in real time. Multiple acquisition presets are provided: live time, real time, integral peak count, peak area, MDA and uncertainty.

Associated Software

The unit is supported by the ORTEC standard MAESTRO™ MCA Emulator, which has been extended to support easy set up of all the instrument functions via the USB hardware interface. The philosophy is that it is easier, in general to set the instrument up for use "back at base" using a large-screen PC, but that if necessary, settings changes may be made in the field, with no PC present. The settings can be protected by password, so that they can not be inadvertently changed. Two levels of passwords are used to allow some functions to be changed and not others. If a password is set, the password must be entered when the digiDART is powered on. The instrument is compatible with all of the ORTEC analysis packages, including versions of MGA++ and PC/FRAM Isotopic ratio packages, and products for the ISOTOPIC analysis of soils and containers as well as general purpose gamma-analysis packages. To aid developers, programmer's toolkits are available.

Comparative performance data

In a recent LANL evaluation[4], the latest ORTEC digital laboratory spectrometer, the DSPEC Plus was evaluated and considered to be "highly recommended." It may therefore be considered as a suitable benchmark for comparison purposes. The new portable MCA was compared to the DSPEC Plus under conditions which are similar to those pertaining to many safeguards measurements. The data were taken with a 500mm^2 planar geometry detector.

Figure 4 shows the 122 keV resolution at low count rate as a function of filter rise time. It shows the familiar degradation in resolution as the filter rise time gets very short.

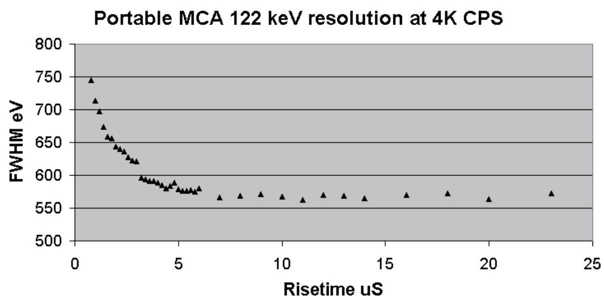

Figure 4 Portable MCA 122 keV resolution as a function of filter rise time

Figure 5 shows comparative system throughput at 2.2 μS filter rise time. The performance from the portable instrument is very similar to that of the benchmark DSPEC plus; if anything it is slightly superior.

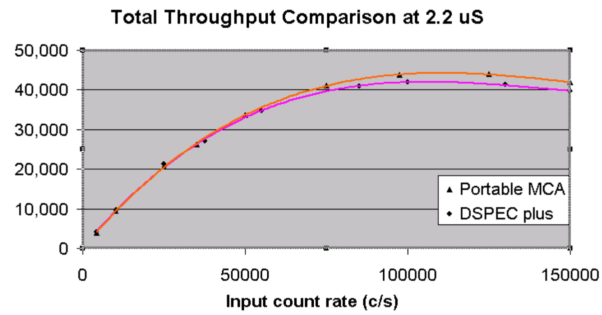

Figure 5 System Throughput, comparative data

Figure 6 shows that in terms of 122 keV resolution, once again, the two systems are very close.

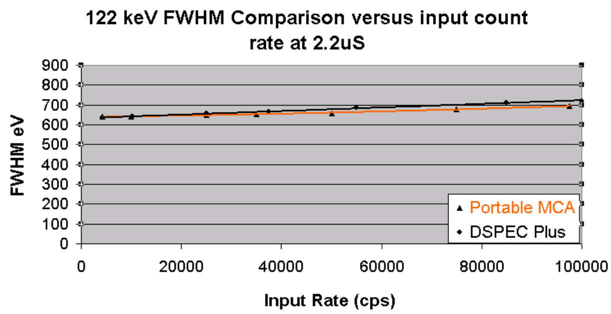

Figure 6 Comparative resolution data

Figure 7 shows that the portable instrument exhibits slightly superior peak count-rate stability to the DSPEC plus system.

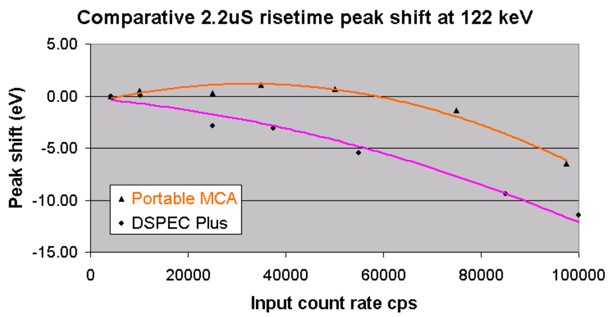

Figure 7 Comparative peak count rate stability data

Conclusion

A new and innovative digital high performance portable MCA has been developed and tested.

A new and innovative digital high performance portable MCA has been developed and tested. It has been shown to provide performance at least equivalent to the best laboratory grade, digital spectrometer. Its package and display provide superior ergonomic features to other portable spectrometers and its built-in display, spectral storage and analysis capabilities extend the usefulness of handheld MCAs.

Refs:

1. D.T. Vo, P.A. Russo and T.E. Sampson, "Comparisons between Digital GAMMA-Ray spectrometer (DSPEC) and Standard Nuclear Instrumentation Methods (NIM) Systems, Los Alamos report LA-13393-MS (October 1997)

2. J.K. Halbig and S. Klosterbuer "The Mini-MCA: An Intelligent Inspection Instrument." Presented at the International Symposium on Recent Advances in Nuclear Material Safeguards, Vienna Austria 1982.

3. Twomey, T. R., Bingham, R. D., Keyser, R. M. "Authentication and data quality monitoring with Safeguards HPGe detector systems," to be published

4. D.T Vo, "Comparions of the DSPEC and DSPEC plus Spectrometer Systems," Los Alamos report LA-13671-MS, 1999