A SELF-CONTAINED ENERGY & PULSE SHAPE LIQUID SCINTILLATION SPECTROMETER

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INTRODUCTION

The increase in nuclear energy applications and the use of technically enhanced sources of radioactivity engenders a need for rapid, low-level techniques to detect and quantify alpha radionuclides. Existing methods often require extensive chemical separations, ion exchange and thin film deposition onto flat surfaces. Counting is performed with surface barrier or gas flow proportional instruments. Occasionally tracer radionuclides are needed to determine the variations in chemical procedures or plating efficiency while prepared standards are used to correct for self-absorption and backscatter. The existing methods may not be feasible for some applications or for field measurements.

Liquid scintillation alpha spectroscopy is a viable alternative to the methods described above. Coupled with solvent extraction techniques, alpha emitter recovery and counting efficiency can approach 100%. The 4π counting geometry eliminates backscatter and self-absorption. Pulse shape discrimination (PSD) signals may be used to segregate alpha particle from beta-gamma decay events. The concept is called Photon Electron-Rejecting Alpha Liquid Scintillation (PERALS) spectrometry. PSD alpha scintillation spectrometers have been developed and applied to the assay of uranium and thorium concentrations in phosphate fertilizers [Bo79,Me80] and ^{210}Po in a uranium mill circuit [Ca81,McK83].

MODULAR PERALS SPECTROMETER

The Radiation Measurements Facility at Arizona State University has attempted to develop a portable PSD alpha spectrometer [Kl81]. The PSD circuit used in the portable system was designed by Thorngate [Th77,Th78]. However, the electronics suffered two instability problems, "walk" and "jitter". Walk refers to the trigger level of a measurement with respect to the amplitude of the peak; for example, a trigger level of 0.25 volt occurs at greater percentage of a 1.0 volt signal than a 10.0 volt signal. Jitter refers to the changes in the trigger level timing due to fluctuations in the signal. To compensate for the instabilities it was necessary to perform frequent adjustments of several interacting potentiometers. A high speed oscilloscope and a pure alpha-emitting sample were needed to perform the adjustments. Therefore, it was decided to reevaluate the electronic schemes published by Thorngate and others. The objectives were to determine if the electronics in the PSD circuitry could be improved and the instabilities eliminated.

The resulting electronic circuit incorporates the ideas of Alexander and Goulding [Al61] as well as Thorngate. Figure 1 is a block diagram of the new electronic scheme. Referring to Figure 1, the photomultiplier tube anode pulse (point A) is integrated by the pre-amplifier. The signal branches (point B) into an upper and a lower channel and an output which is delayed for 400 nanoseconds. The delay allows the integrated signal to reach its peak voltage (point E). The upper and lower channels each contain a percentage of the non-delayed signal to be used in the compatators. The upper channel contains a larger percentage of the signal than the lower. The signals in the upper and lower channels (points C & D) are fed to separate comparators and produce a fixed fraction of the signal (points F & G) for use in the time-to-amplitude-converter (TAC). The comparators trigger as the rise of the delay signal crosses the voltage settings determined by the upper and lower channels. The time difference between the comparator trip points is processed by the TAC and produces a PSD spectrum (point H) [Ca85].

Figure 2 is a diagram of the modular PERALS spectrometer. The spectrometer is six NIM modules wide. It contains a high voltage power supply, a photomultiplier tube, a sample holder, and the PSD and pulse-height amplification electronics. The unit fits into a standard 6 or 12 wide NIM bin. As shown in the figure, outputs from the PSD portion of the system may be sent directly to a multichannel analyzer (MCA) to provide gross alpha and beta/gamma decay information. In addition, the PSD signal may be used to gate the MCA and reject all beta/gamma decay events. Thereafter, only the alpha decay events from the energy pulse-height amplifier will be accepted by the multichannel analyzer. The resulting alpha energy spectrum does not contain any beta/gamma interference.

Two figures of merit defined by Thorngate (Th77), the beta-gamma Rejection Ratio and the Background counts, may be used to evaluate the performance of the system. The Rejection Ratio is the unit's ability to reject the beta/gamma decay events occurring within the sample. Background is the unit's ability to reject the environmental beta/gamma events. The new PERALS spectrometer exhibits a slightly improved Rejection Ratio over Thorngate's (our system = 99.98% , Thorngate = 99.95%) but had a higher, yet acceptable background (our system = 0.046 cpm, Thorngate = 0.002 cpm). The new system has less jitter and walk and does not require frequent adjustment. It is hoped that the system will be commercially available in the future.

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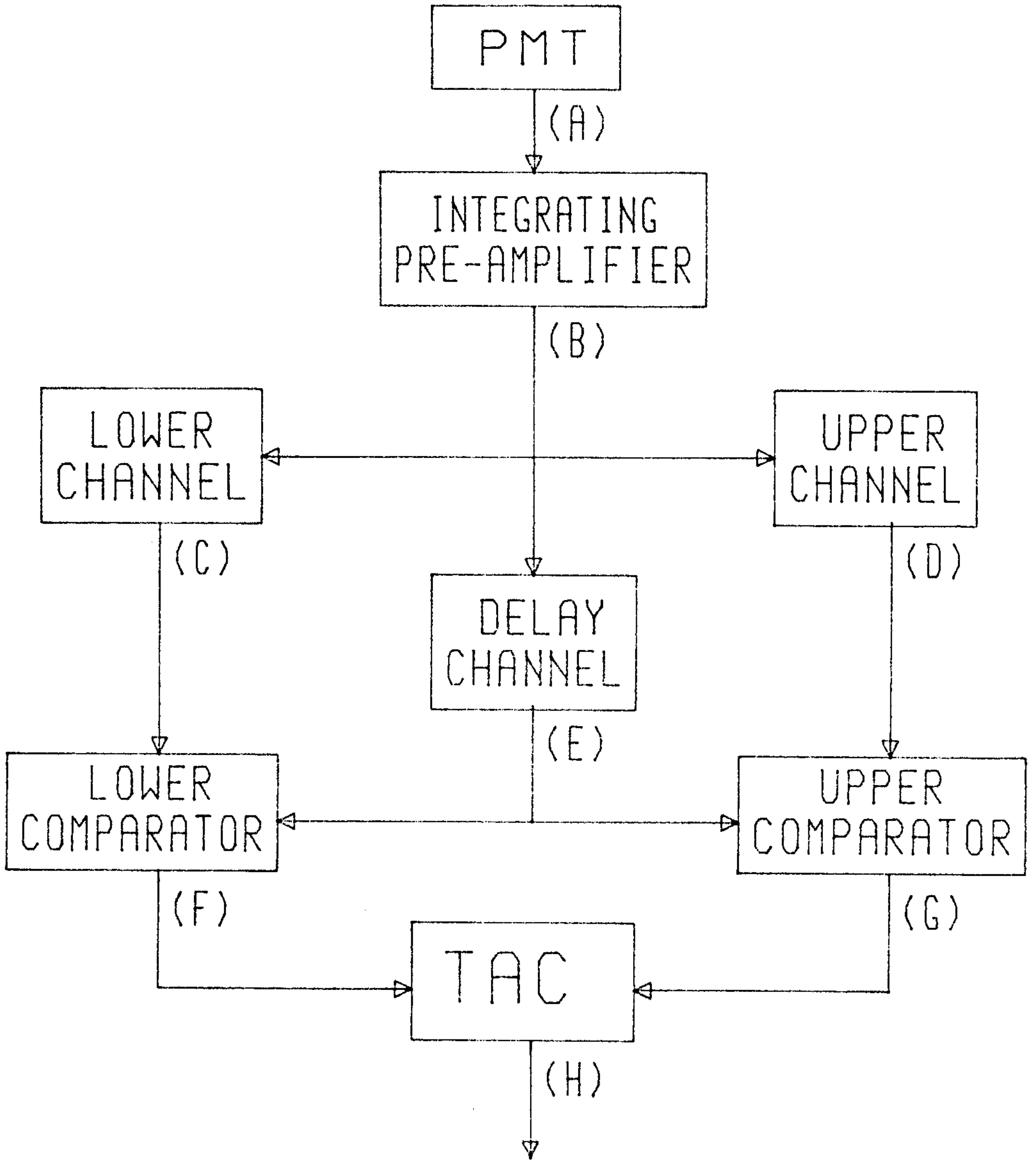

FIGURE 1. BLOCK DIAGRAM OF NEW ELECTRONICS

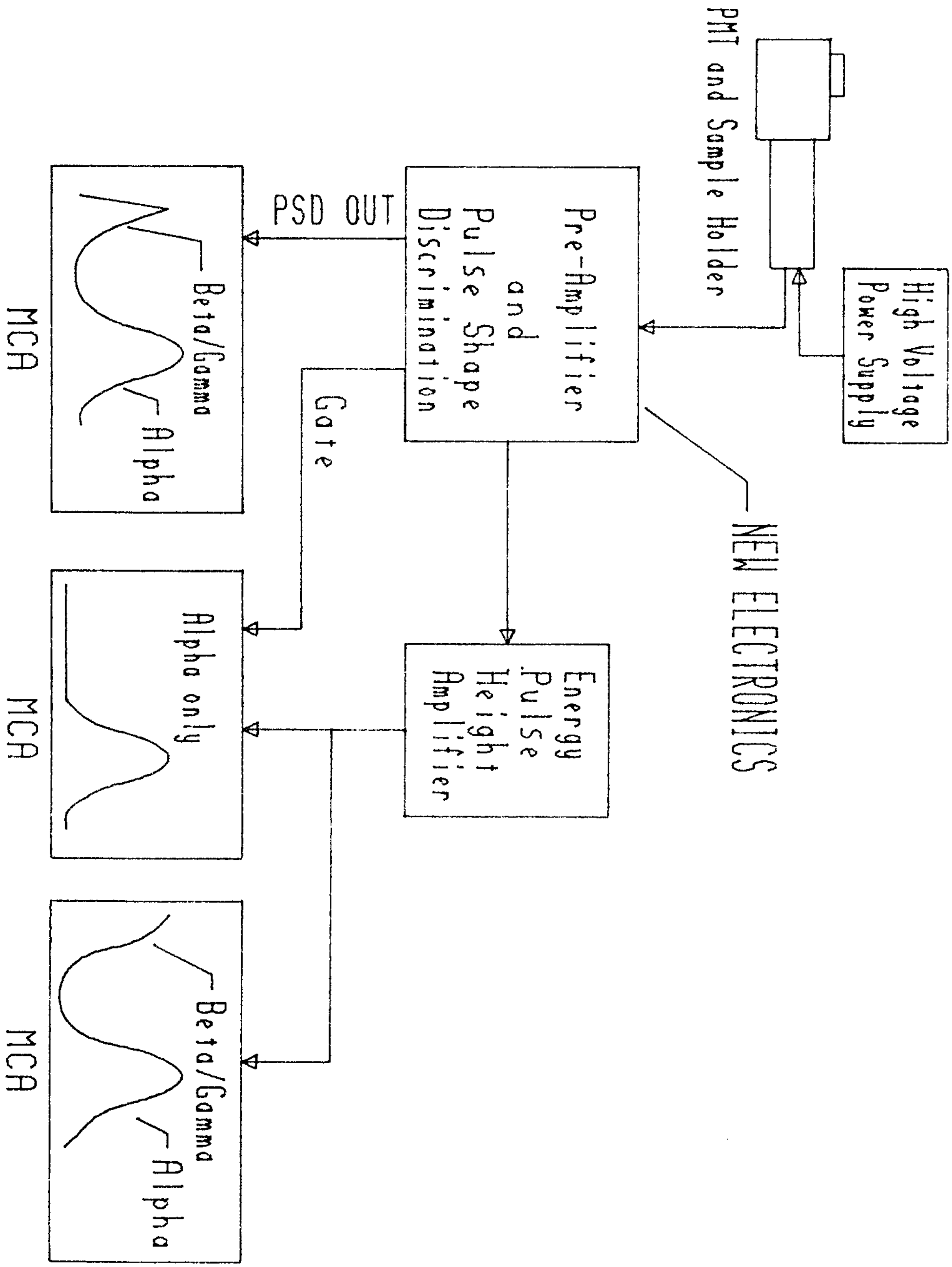

FIGURE 2. PERALS SPECTROMETER