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Development of multi-channel high time resolution data acquisition system for TOT-ASIC

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We developed a multi-channel high time resolution data acquisition (DAQ) system for time-over-threshold (TOT)-ASIC. The developed field-programmable gate array (FPGA)-based DAQ is composed of 144 channels per board with an ethernet readout for measuring energy and timing information simultaneously. The measured time resolution of the developed DAQ board is up to 62.5 ps. The proposed DAQ with TOT-ASIC can be potentially used for several radiation detection applications, such as positron emission tomography (PET) and Compton imaging. The DAQ board can be applied in PET and has been named as PETNET (PET readout board with a high-speed network).

Synchronizing all boards

Figure 1 illustrates an example of a system using PETNET. There is an electron–positron reaction point at the center of the system, and two 511 keV γ-rays that fly out to the opposite directions are detected by two PET detectors simultaneously. The tangent line, including the reaction point, is obtained by the time coincidence, which is obtained from the outputs of the opposite two detectors.

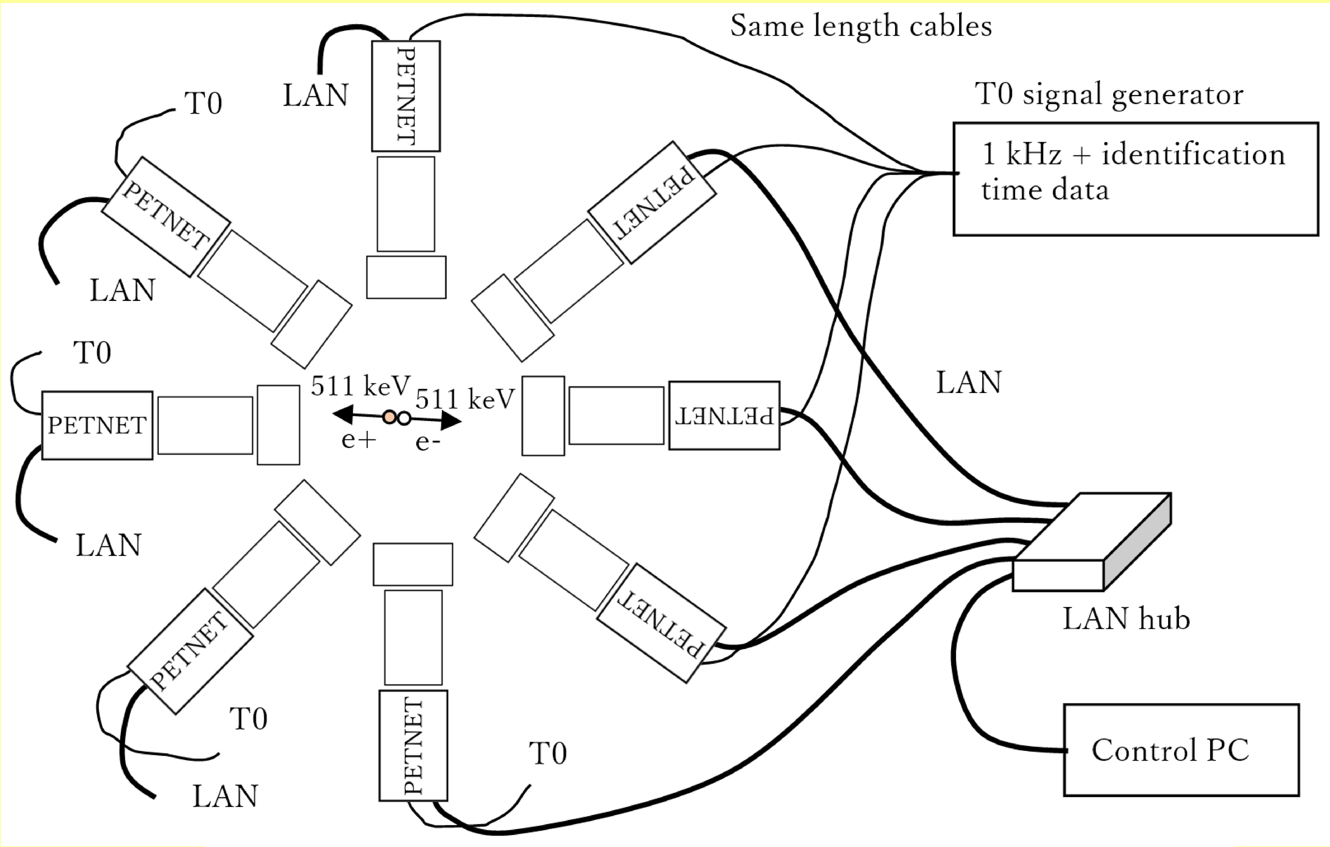


Fig. 1. Example of using PETNETs.

Development of 125ps & 62.5ps-systems

In the first version, the DDR method used for memory access is typically adopted. Each channel is read by a 500 MHz clock with a time resolution of 1 ns. Fig. 2 (a) shows that two-bit data are obtained at every rising edge of the 500 MHz clock.

In the second version, the delay-line method used for the time-to-digital converter (TDC) is usually adopted. The PETNET achieved 144 channels and 96 channels per board with a time resolution of 125 ps and 62.5 ps, respectively. Fig. 2 (b) demonstrates an example of the 125 ps time resolution. Sixteen flip-flops are arranged to cover a delay element of 2 ns, and 16-bit data are obtained at every rising edge of the 500 MHz clock.

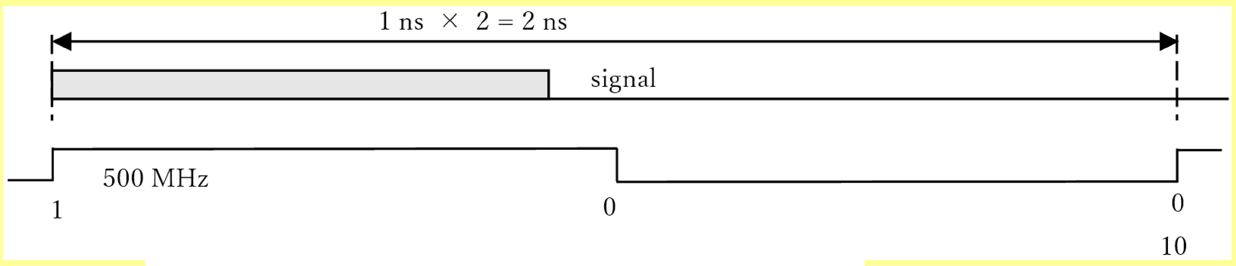
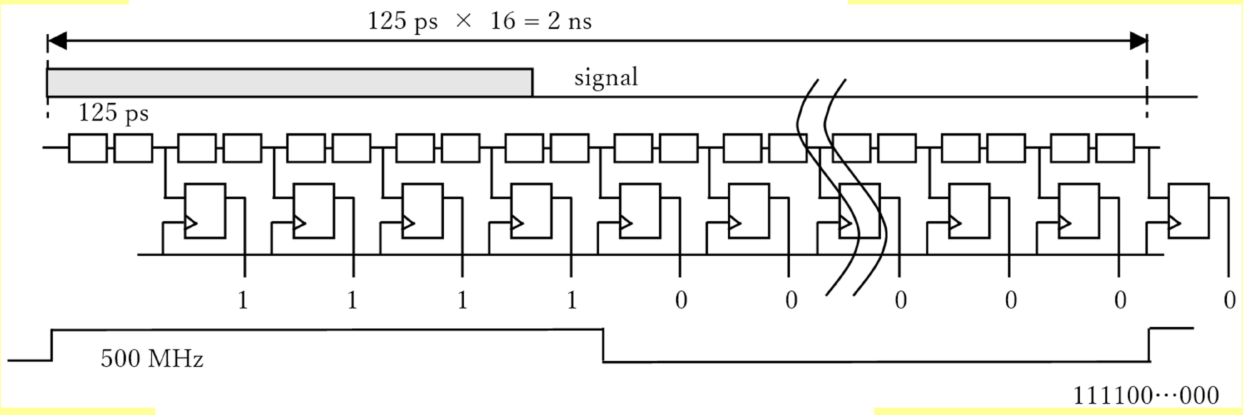
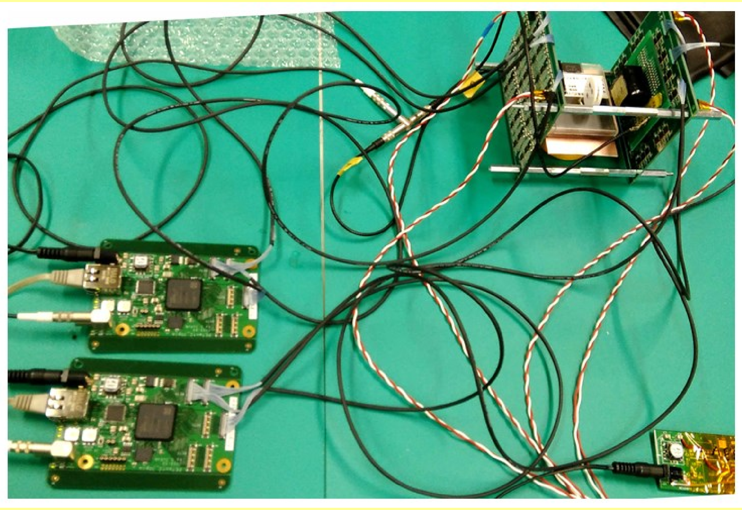


Fig. 2 (a) DDR method



(b) Delay-line method

Experiment TOT-PET by the DDR



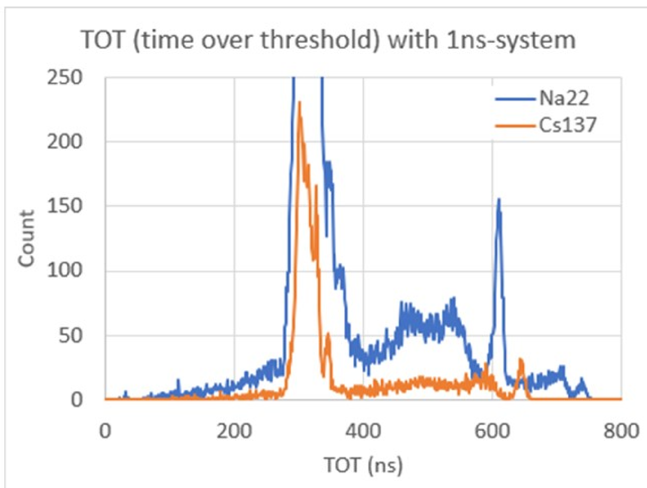


Fig. 3 (a) Layout (b) TOT of ^{22}Na and ^{137}Cs

The experiment was performed by placing two 8×8 multi-channel PET detectors facing each other and ^{22}Na, which generates positrons, between them. Fig. 3 (a) illustrates the overall experimental layout. The two PETNETs with DDR having a time resolution of 1 ns were attached to the two detectors. Fig. 3 (b) demonstrates the TOT distributions of all the detectors for ^{22}Na and ^{137}Cs.

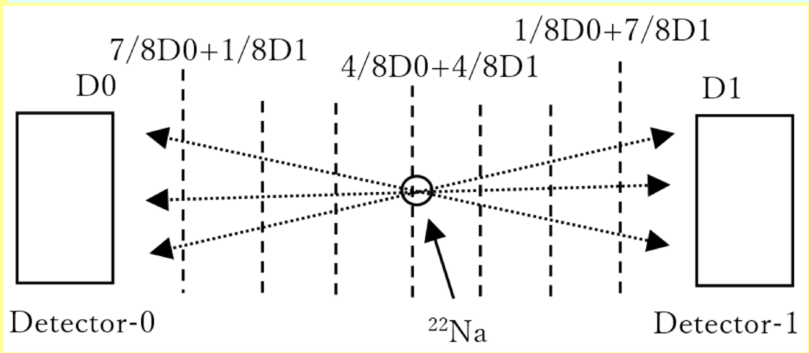
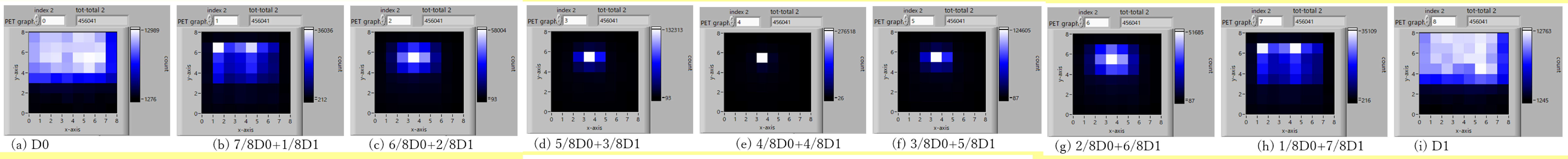


Fig. 4 (a) Cross-sections of ^{22}Na

Figure 4 (a) presents the principle of cross-sectional images with ^{22}Na. The 511 keV γ-rays, which are two pairs with opposite directions, were detected using the two PET detectors simultaneously. Fig. 4 (b) shows 2D images of the cross-sections.



(b) 2D images of the cross-sections

Experiment the delay-line

Figure 5 (a) depicts the overall experimental layout. Using two PETNETs, one was programmed as a test signal generator. Each TOF was measured as in (b), (c), and (d) by changing the length of the T0 signal cable. As shown in Fig. 5 (b), a length of 10 cm was difficult to distinguish. However, from Fig. 5 (c) and (d), a length of 10 cm was sufficiently distinguished Because the TOF distribution of 62.5 ps in (d) has approximately 150 ps as the full width at half maximum, a position resolution of 4.5 cm at the light speed was obtained.

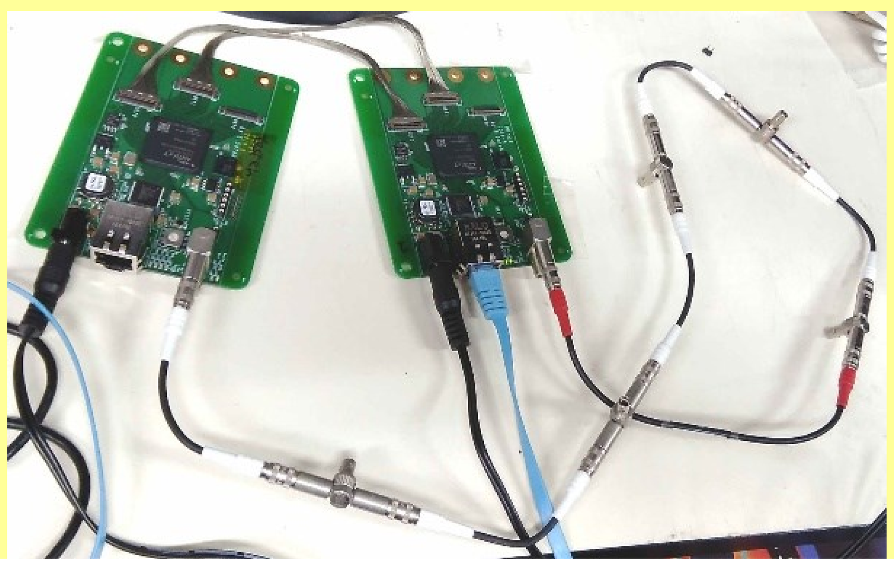
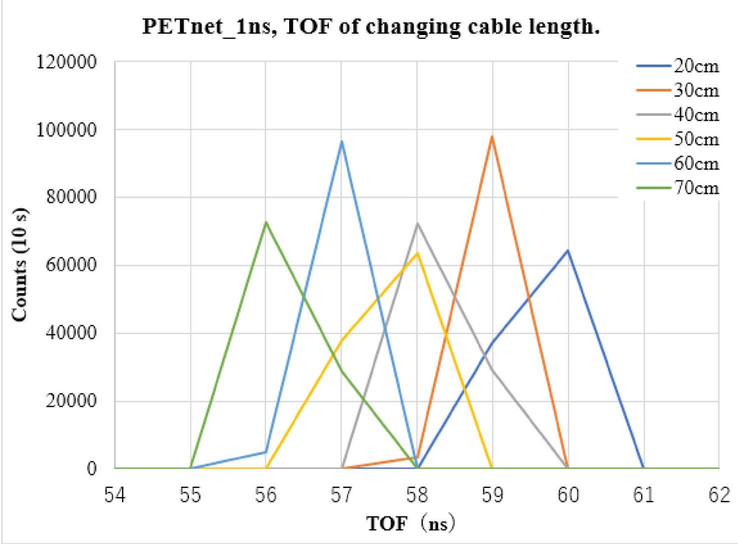
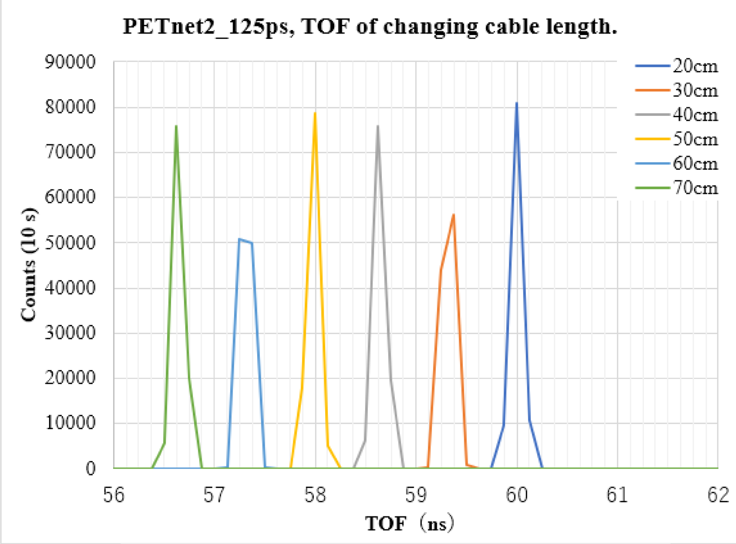


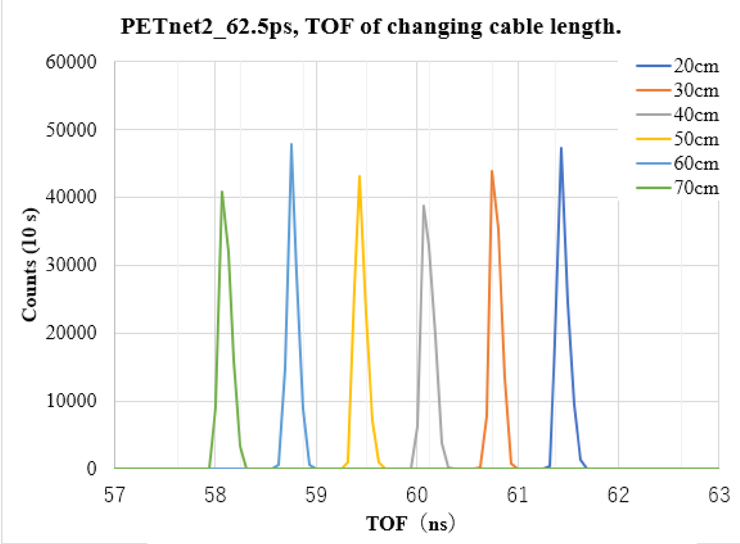
Fig. 5 (a) Changing cable length



(b) 1ns-DDR



(c) 125ps-Delay-line



(d) 62.5ps-Delay-line

Acknowledgments

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