IV. 6. Development of a Pulse Height Estimation Method for a High Resolution PET Camera with Position Sensitive Semiconductor Detectors

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Introduction

In order to achieve high spatial resolution, application of semiconductor detectors to animal PET cameras is an effective way. Semiconductor detectors can be small, and these detectors enable fine spatial sampling. But, use of small semiconductor detectors may cause decrease of system sensitivity, because of vacancy between detectors aligned densely.

Against this problem, we propose use of position sensitive semiconductor detectors (PSD), which are consisted of continues crystal. Generally, one of electrode of these detectors is a resistive layer on which several wire are connected to obtain signal. Because there is a correlation between an energy deposited position in the detector and outputs fraction from detector, the position can be identified with calculation. But, devices which can acquire pulse height information, like ADCs, are necessary for position analysis, so that a measurement system become large, when considering of detectors number in a PET camera. So, it is desirable that pulse height information is acquired with a simple way. We report about pulse height estimation method based on pulse shape analysis without ADCs.

Principle

Pulse height of an analog signal from a radiation measurement circuit which is consisted of preamplifiers, amplifiers, and so on, is proportional to energy deposited to a detector, and a pulse shape depends on time constant of the circuit. In order to estimate pulse height, we propose amplitude to time conversion (ATC) method with a comparator. When an analog signal is input to comparator, a width of a comparator signal is determined uniquely by analog pulse height. Figure1 shows an example of ATC method.

Assumed that an analog signal rises quickly, and fall exponentially, the signal, which arise at t = 0, is expressed in next equation.

$$V = Vo \exp\left(- t/\tau\right) \qquad \text{(Equation 1)}$$

So, correlation between output signal amplitude and comparator output width Δt is indicated by a following equation, when reference voltage of comparator is Vref.

$$Vo = Vref \exp\left(\Delta t/\tau\right) \qquad \text{(Equation 2)}$$

Experiments and analysis

The estimation method was evaluated with a CdTe detector which was a candidate of detectors for a semiconductor PET camera. The CdTe detector was coupled to a linear amplifier via a charge sensitive preamplifier, and amplifier outputs signals were observed and stored with a digital oscilloscope as digital pulse shape data. In order to assume comparator outputs, periods when signal was over reference voltage which was set at several conditions was calculated from the pulse shape data.

A typical pulse shape is shown in Fig 2. Although it is assumed that a pulse rise time can be neglected in equation (1) and (2), rise time is considerable in actual signal, so that Δt' is smaller than Δtc, when Δt' is a period of a actual signal and Δtc is a period calculated from the signal amplitude with equation (2).

Figure 3 shows that fraction of Δt' to Δtc. Because the fraction is unique in a constant reference voltage, accurate signal amplitude can be calculated by acquiring fraction f experimentally. A following equation is derived from equation 1 or 2 with f.

$$Vo = Vref \exp\left(f\Delta t'/\tau\right) \qquad \text{Equation (3)}$$

Applying the equation (3), signal amplitudes Vp(calc) were calculated according to acquired digital signal data. Figure 4 shows correlation between Vp(calc) to actual signal amplitude Vp(measurement). The correlation indicates good linearity.

Conclusion

The simple Method to estimate pulse amplitude without an ADC module is proposed for PET camera which is consisted of a large number of detector elements. In experiments with CdTe detector, it was confirmed that a calculated signal amplitude is determined uniquely by Δt,which is a period when signal is over reference voltage. And accurate amplitude can be informed by using a correction fraction f which is obtained experimentally.

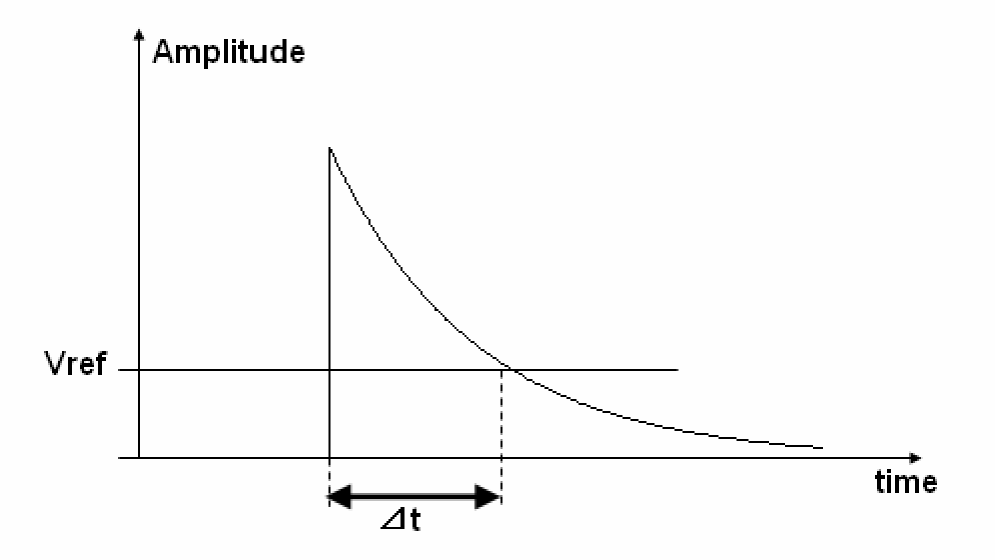

Figure 1. Principle of ATC method.

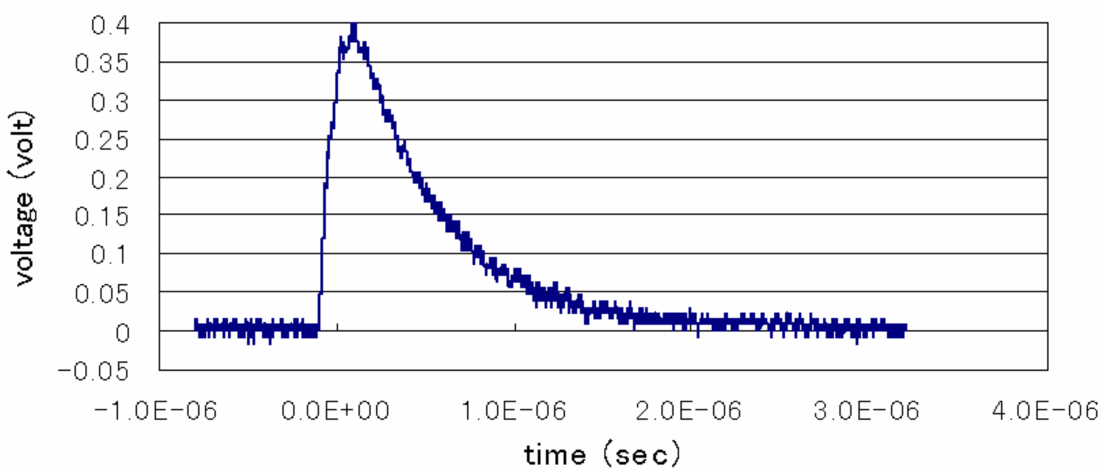

Figure 2. Actual signal shape from CdTe detector.

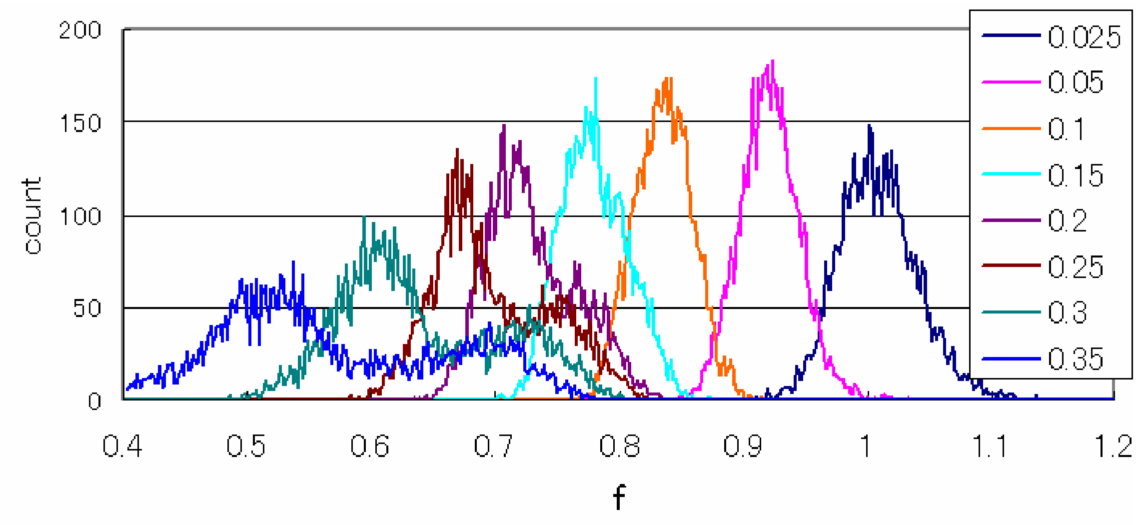

Figure 3. fraction of Δt' to Δtc in various reference voltage.

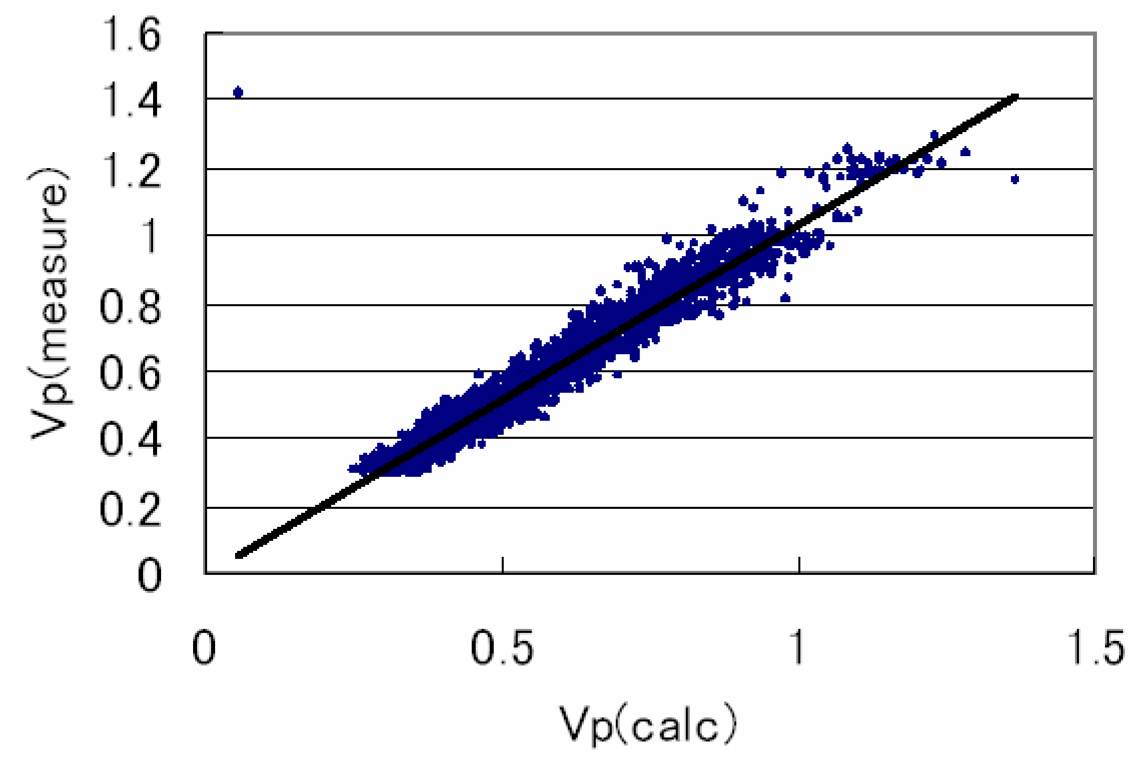

Figure 4. correlation between measured signal output voltage and calculated signal output voltage with ATC method.