Evaluation of basic performance of Charge-to-Time Converter Module (QTM)

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Advanced accelerator technology has been giving us the high-intensity radioactive ion beams. We can now make various experiments with those beams. However, as the beam intensity increases, it becomes more and more difficult to take full data because of growing dead time of data acquisition system. It is mainly limited by relatively long conversion time of Analog-to-Digital Converter (ADC) or Charge-to-Digital Converter (QDC). To make it shorter, we developed general purpose Charge-to-Time Converter Module (QTM) [1, 2] which has much shorter dead time than ADC and QDC. The heart of QTM is the Charge-to-Time Converter (QTC) chip, which is developed originally in Kamioka Observatory [3] and produced by IWATSU Test Instruments Corporation. QTM converts the charge of signal into the width of rectangular output pulse as shown in Fig. 2 in ref. [2]. Therefore by using QTM, we can take information of time and charge at once.

QTM is a NIM module including two QTC chips and each chip has 3 channel inputs. A QTC chip accepts input charges up to about 50 pC. Input signals are equally divided into three identical ones and two of them are attenuated by factors of 7 (medium gain) and 49 (large gain). Thus dynamic range of input charge is expanded up to 2.5 nC. QTM has 6 inputs with 50 Ω termination and 18 (2x3x3) LVDS outputs. Internal parameters such as threshold or integration time can be reconfigured via USB connection.

To evaluate basic performance of QTM, we measured the time and the charge resolution of QTM in medium gain (50–350 pC) and compared them to those of the traditional setup using Time-to-Digital Converter (TDC) and QDC. The setup of this measurement is shown in Fig. 1. Input signal, which was generated by Multifunction Synthesizer WF1946A (NF corporation), had the trapezoidal shape with the lower-base width of 50 ns and the rise- and fall-time of 10 ns as shown in Fig. 2. Input charge was varied by adjusting the height of input pulse. QTM threshold was fixed to 15 mV. To digitize timing signals, TDC V775 (CAEN) and multi-event non-stop TDC V1190 (CAEN) were used, and for the traditional system, input charge was digitized by QDC V792 (CAEN).

Figure 1. Electronic scheme of the measurement.

Figure 2. Input signal and QTM output signal. QTM converts the charge of input signal into the width of output pulse.

Figure 3 and 4 show the results of measurements of time resolution and charge resolution, respectively. In Fig. 3, time resolution of the system including QTM plus V775 (indicated by the stars) is about 40 psec, while the resolution of the traditional one (i.e. Discr. plus V775, indicated by the circles) is about 30 psec. These results show the usability of QTM. However, time resolution of the new system (i.e. QTM plus V1190) is seemingly worse, but it seems to be due to the bad time resolution of V1190 (~100 psec LSB), because the system including QTM with V775 (typically ~30 psec LSB) has rather good resolution (this is even below the catalog value of QTM) closing up to the traditional system. The new system is enough usable for processing of data from plastic scintillators because the current time resolution of the new system is on par with that of plastic scintillators. To achieve better resolution and shorter dead time simultaneously, we still need a good multi-event non-stop TDC.

On the other hand, the charge resolution of new system is about 1.4 pC, worse than that of traditional system being ~0.5 pC as in Fig. 4. But it is sufficiently good in some application e.g. γ-ray detection with LaBr$_3$(Ce) scintillator, which is expected to be a new-generation γ-ray detector, because it is still below 3% under the condition that input charge is greater than 50 pC and independent from the amount of input charge. In addition, if input charge is smaller than 50 pC, one should use the small gain. The analysis to deduce the charge resolution with small gain is in progress.

We also carried out spectral measurement with LaBr$_3$(Ce) scintillator. The spectrum of γ-ray emitted...
from $^{60}\text{Co}$ and $^{137}\text{Cs}$ source was taken with a system including QTM and one including QDC. The result is shown in Fig. 5. Upper panel shows the result with QDC, lower with QTM. The result with QTM seems as good as that with QDC.

QTM was already used in an experiment using the SHARAQ Spectrometer [4] as a readout circuit of plastic scintillators and provided good performance.

In conclusion, QTM in medium gain is sufficiently usable in actual experiment as it is now and further analysis of its performance in both small and large gain is needed.

References