# 5 - 13 A Design of Current to Frequency Converter for Dose Monitoring in Heavy Ion Therapy

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In order to make sure that the tumor is irradiated by a uniform and adequate dose and the surrounding tissues are damaged as little as possible, we need to monitor and measure the irradiation dose in real time. The dose monitoring probe of the beam intensity monitoring system in the deep-seated tumor therapy is an integral ionization chamber, its' output current signal is proportional to the beam intensity. The output signal of the ionization chamber is less than 1 μA. In order to measure the weak current signal, a new current to frequency converter has been developed.

The principle diagram of the current to frequency converter is shown in Fig. 1. The output current I of the ionization chamber is integrated on capacitor C. In order to match the range of the output voltage of integrator with the range of output voltage of DAC, the output voltage of integrator is attenuated, and then it compares continuously with a variable threshold voltage generated by a digital to analog converter (DAC) at the input of comparator CMP. The input data of DAC is from a counter constructed in a CPLD. The number in counter is increased each time when the CMP generates an output, and the threshold voltage of CMP is increased with a fixed voltage each time. When the number in counter reaches the minimum value, the control circuit in CPLD gives a signal to switch SW1 closed, the integrator is discharged.

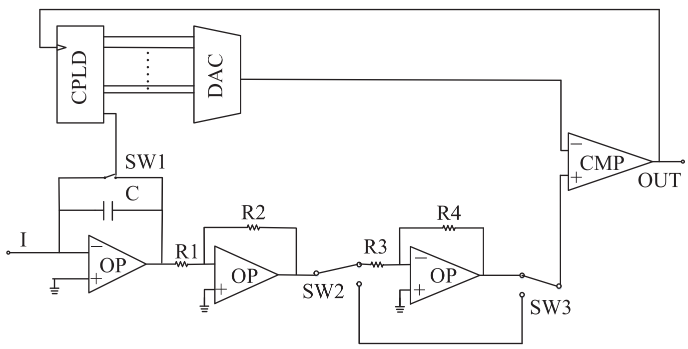


Fig. 1 Principle diagram of the current to frequency converter.

Fig. 2 (a) shows the output waveform of a single operating cycle when the input current is −0.01 nA, and Fig. 2 (b) shows the partial waveform of Fig. 1 (a). The upper waveform in Fig. 2 is the output of DAC, and the lower waveform in Fig.2 is the output voltage waveform of integrator after processed by conditioning circuit.

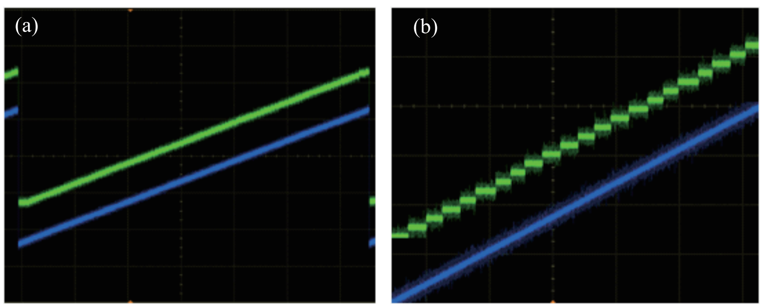


Fig. 2 (color online) output waveform of the circuit. (a) the output waveform of a single operating cycle; (b) a partial waveform of (a).

In order to meet the requirements of different measurement accuracy, two kinds of circuits with different conversion precision were developed: one is 10 pC/pulse and another is 0.5 pC/pulse. The circuit with conversion precision of 10 pC/pulse can measure current from 0.01 nA to 60 μA, the bipolar current can be measured without complex operation when the polarity of input current is changed. The linearity is better than 0.464 34% when negative current is measured from 0.1 nA to 70 μA, and it's better than 0.342 88% when positive current is measured from 1 nA to 60 μA. The linear fitting in full measurement range is shown in Fig. 3. The circuit with conversion precision of 0.5 pC/pulse can measure current from 0.01 nA to 500 nA, and the linearity is better than 0.041 68% in full range. The linear fitting in full measurement range is shown in Fig. 4. The circuits developed can well satisfy the requirements of dose monitoring in heavy ion therapy and other practical applications.

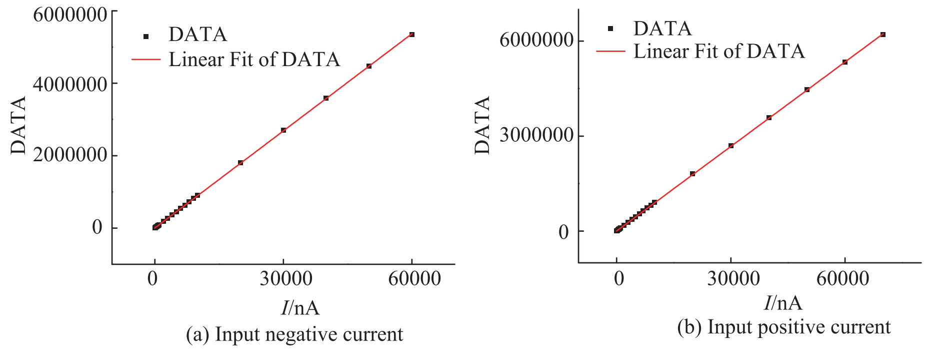


Fig. 3 (color online) Linear fitting of circuit with precision of 10 pC/pulse.

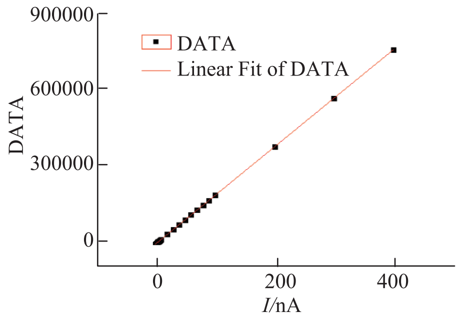


Fig. 4 (color online) Linear fitting of circuit with precision of 0.5 pC/pulse.

# 5 - 14 Development of the Readout Electronics System for the Prototype of TOF-PET

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As the disadvantages of large scale, complex circuit, high power consumption, the traditional readout electronics system formed by discrete modules is not suitable for the TOF-PET system, a nuclear medical imaging system. Therefore, it is necessary to design and develop a new high integration and low cost readout electronics system for TOF-PET. A readout electronics system for our prototype of TOF-PET has been developing on the basis of application requirements. The principle architecture of prototype of TOF-PET is shown in Fig. 1. There are five parts mainly in the system: the detector unit, the front-end electronics module (FEM), signal processing board (SPB), Coincidence Interface Board (CI), and PC. The FEM and SPB boards developed until now are mainly introduced in this paper.

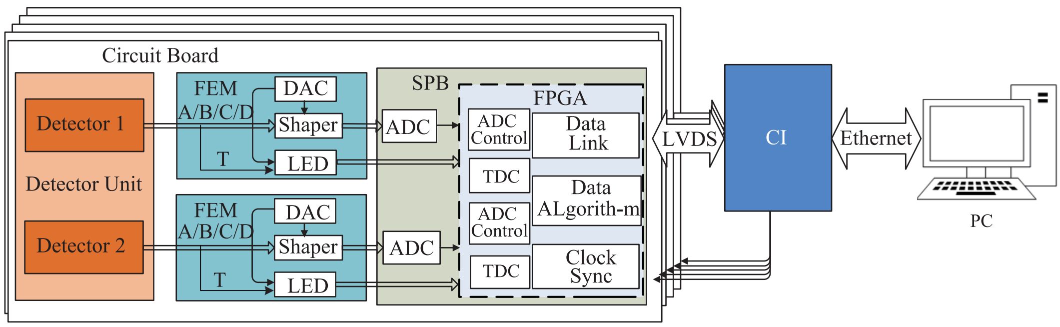


Fig. 1 (color online) The TOF-PET system architecture.

The analog front-end with five channels is hosted in a module called a FEM, the FEM can process signal from each channel independently, the filter, shaping, amplify, discrimination, *etc.* are implemented by FEM. The prototype of FEM board is shown in Fig. 2. The output signals of FEM are formatted and sent through a LVDS bus to a module called SPB, one SPB can face two FEMs. The prototype of SPB board is shown in Fig. 3. The energy signal from FEM tells how much energy deposits into the crystal when the crystal is hit by photon. It is