Abstract

Spectroscopic X-ray imaging is an important development direction in the field of medical CT in recent years. Spectroscopic CT can detect X-rays in multiple energy ranges simultaneously, and assign different weight factors to X-rays of different energies, effectively improving the contrast of X-ray imaging. In addition, it can identify substances based on the differences in their abilities to absorb X-rays. X-ray detection can be divided into energy integration and photon counting according to the detection method. Photon counting detection can eliminate the influence of electronic noise compared to the former and has better energy resolution.

In this thesis, a readout chip for a hybrid pixel detector was designed, using 110nm CMOS technology, with 8×112 pixels, each pixel size is 110 ×110 μm^2. Each pixel contains four digitally programmable thresholds that can simultaneously count photons in four energy ranges, and the counter depth for each energy range is 12 bits. When incident photons interact with the detector on the edge of the pixel or when the pixel size is relatively small compared to the detector thickness, the charge generated by the incident particle will diffuse to adjacent pixels, i.e. the charge sharing effect, which will affect the energy resolution of the pixel and may also cause imaging artifacts due to incorrect photon counting.

To eliminate the charge sharing effect, a correction circuit was designed in the digital circuit section of this chip, which can reconstruct all the charge generated by the incident particle and find the pixel actually hit by comparing the ToT signals of adjacent pixels, and then assign all the collected charge to that pixel. The chip adopts a two-stage amplifier structure in the analog circuit section, which can complete the amplification shaping and charge summation of the signal. The signal amplified and shaped generates ToT signals after the discriminator, and then completes digitization through the ToT counter. Finally, the event is distributed to the corresponding energy counter by comparing with four preset energy thresholds in the threshold comparator module of the digital circuit. Currently, mainstream pixel sizes range from 50 μm to 150 μm, and

implementing charge sharing correction and multiple energy thresholds within such a small circuit area is a huge challenge for chip design. This chip innovatively provides a digital threshold scheme based on ToT technology, implementing four digitally programmable thresholds in each pixel instead of discriminators that are commonly used in photon counting detector systems.

In this thesis, the post layout simulation verification was carried out for the charge sharing correction logic of the analog and digital circuits, the digital threshold comparator, and the energy counter.