

## Abstract

Due to the small size, high gain, high time resolution, low operating voltage, and insensitivity to magnetic fields of the SiPM, the research of SiPM as sensor of the calorimeter has attracted a lot of attention. This work has designed 8-channel readout chips SICCO and SICCC1, which can simultaneously record the hit time and the energy information of particles. The SICCO chip uses the traditional readout structure, including two readout paths, one path uses a TDC to record the arrival time and the other path uses front-end and ADC to save the energy information, three different gear selections are used for the energy detect to cover a large input dynamic range. The test results show the performance of the SICCO is as expected. The linearity input range is from 10  $\mu$ A to 3 mA, and the time resolution is less than 1LSB (25ns) which can be up to 5ns, the dynamic range is 25ns-6.375 $\mu$ s. To improve the time resolution, a new two-step TDC is designed on chip SICCC1. The post simulation results show that the time resolution of the new TDC is 70 ps, the dynamic range is 640 ns, and the RMS is about 3 ps. The SICCC1 chip is under testing now.

## Structure and test results of the SICCO

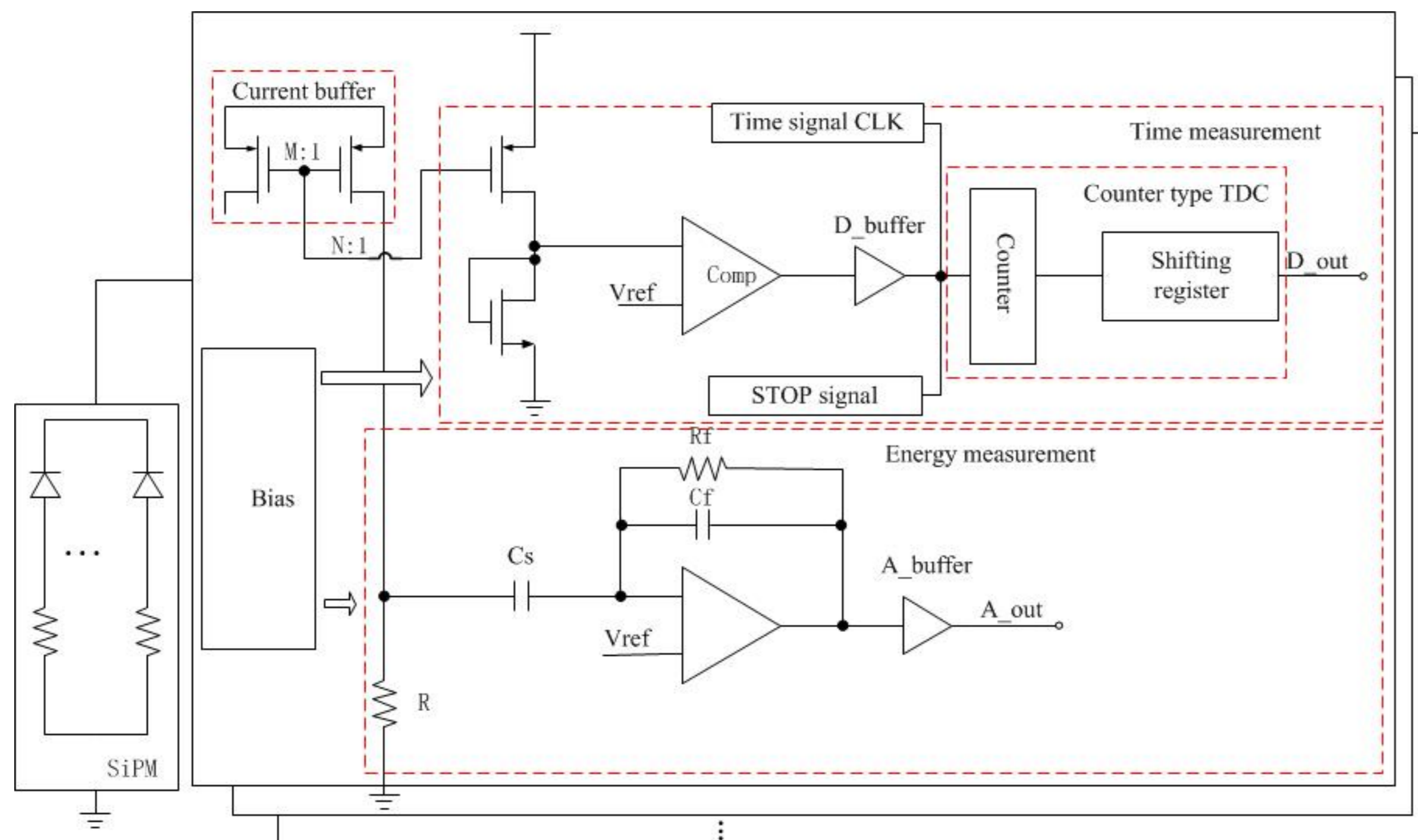
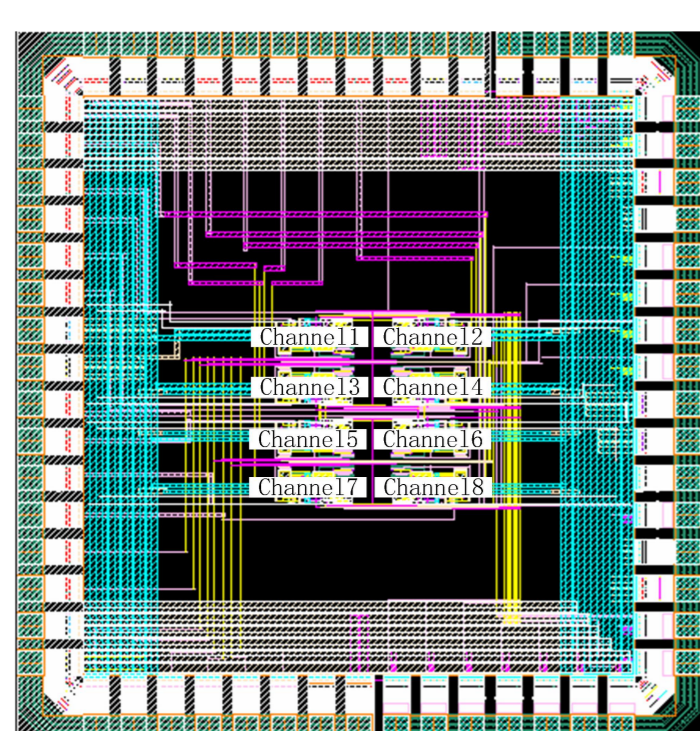


Figure 1. Structure of the SICCO

- ◆ The chip contains two channels: Time measurement and Energy measurement
- ◆ The time measurement path is mainly composed of a hysteresis comparator and a counter-based TDC
- ◆ The energy measurement path mainly includes a capacitor proportional amplifier and a current buffer circuit
- ◆ The analog buffer is designed to drive large capacitive loads offchip



- ◆ The SICCO is fabricated in 130nm CMOS technology
- ◆ The dimension of SICCO is 1.865mm x 1.970mm

Figure 2. The Layout of SICCO

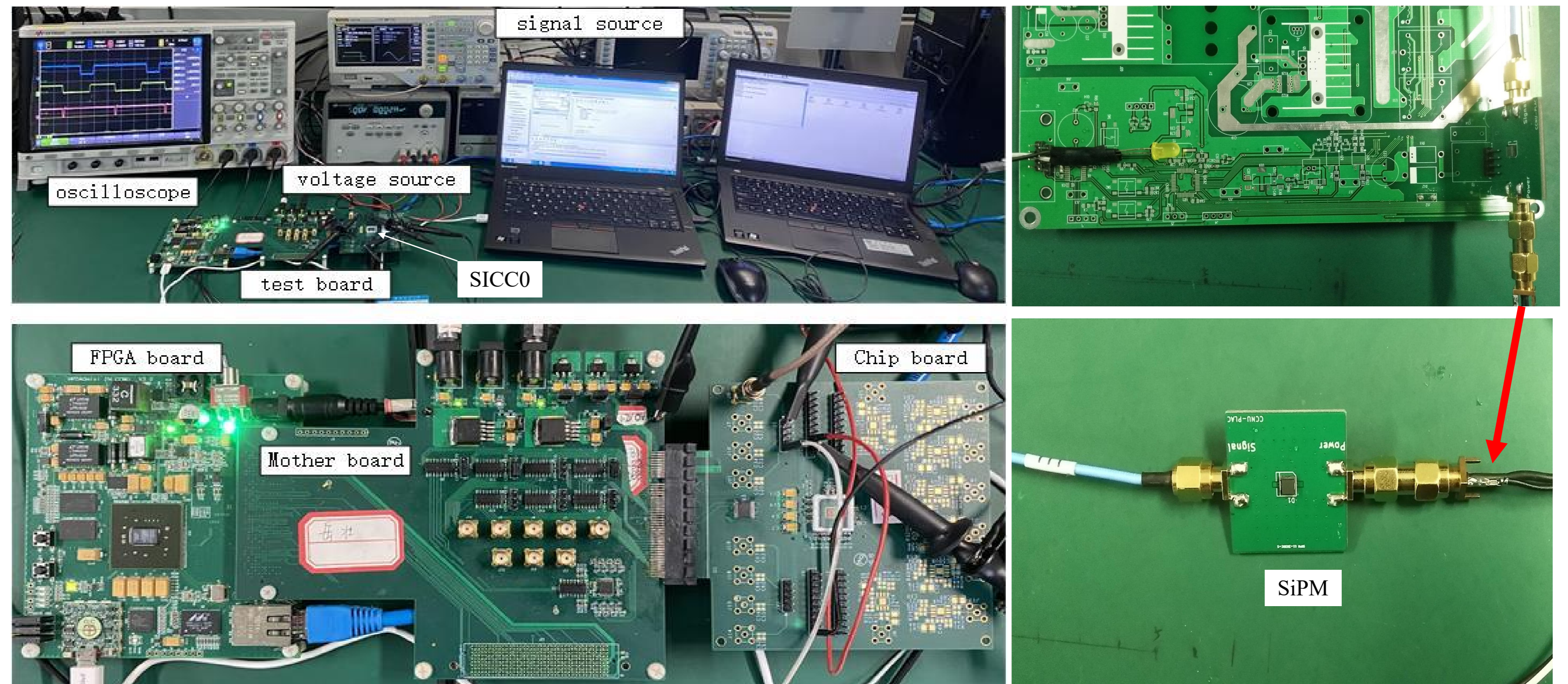


Figure 3. SICCO test platform

Figure 4. SiPM test board

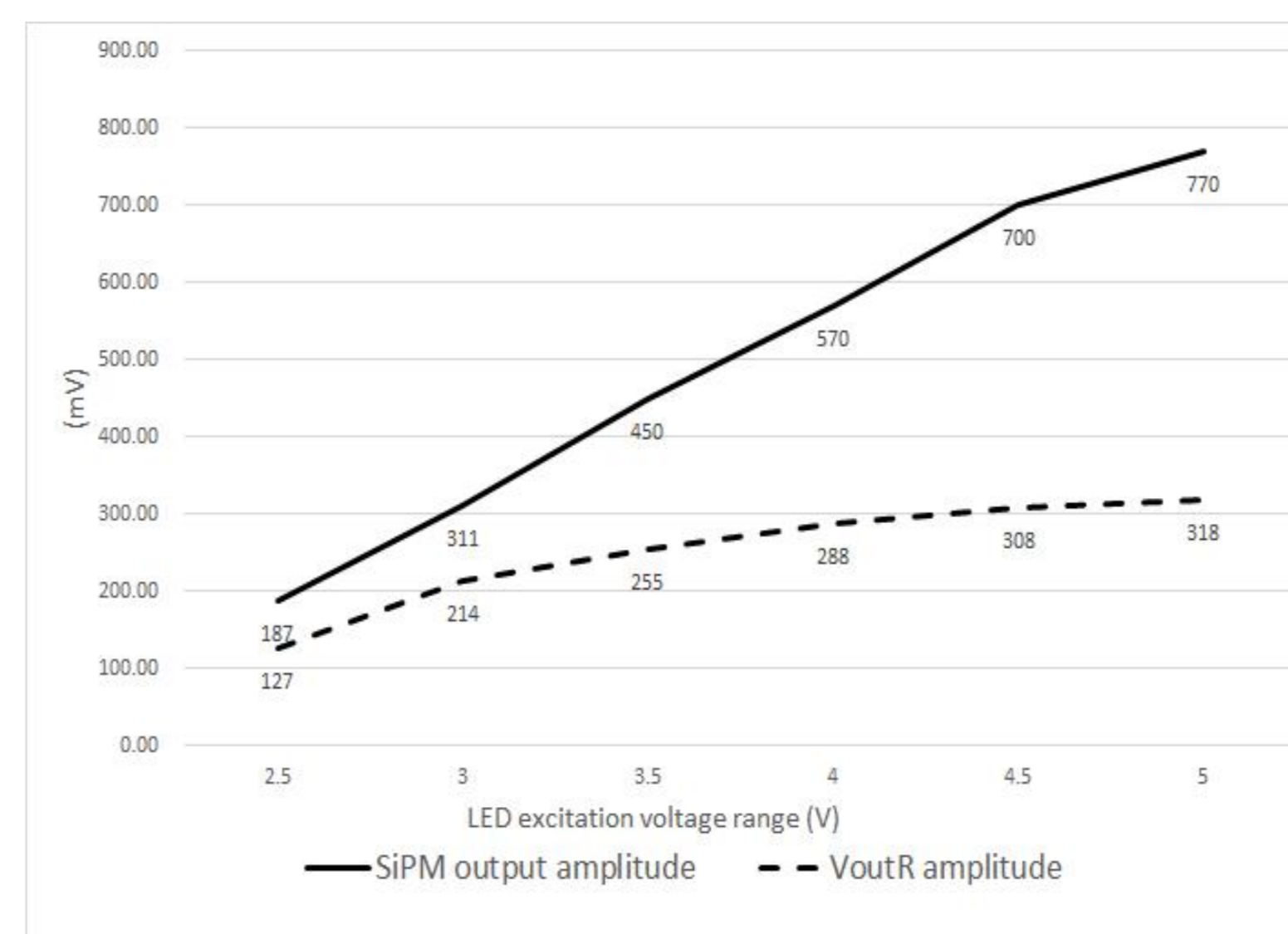


Figure 5. The test results of the current buffer using the SiPM of Beijing Normal University @LED source

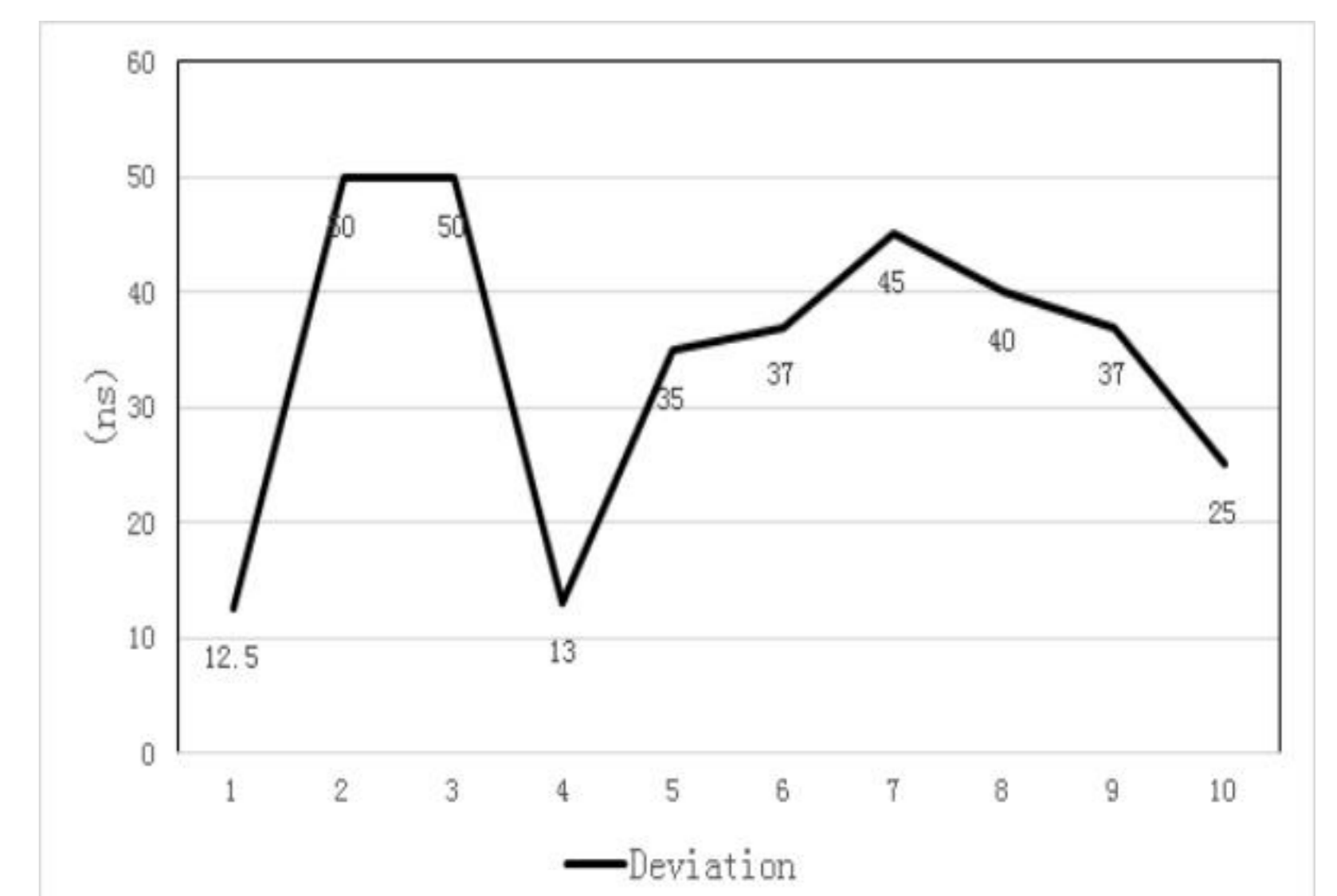


Figure 6. The TDC DNL test results of SICCO chip @ 40MHz

- ◆ The test results of the current buffer are shown in Figure 5, using a LED source, the output of the current buffer is monotonic linear.
- ◆ The test results of the DNL of TDC is shown in Figure 6, operating at the normal working frequency of 40MHz, the time resolution is less than 25ns, and the dynamic range is 25ns-6.375 $\mu$ s.

## Two\_step TDC circuit

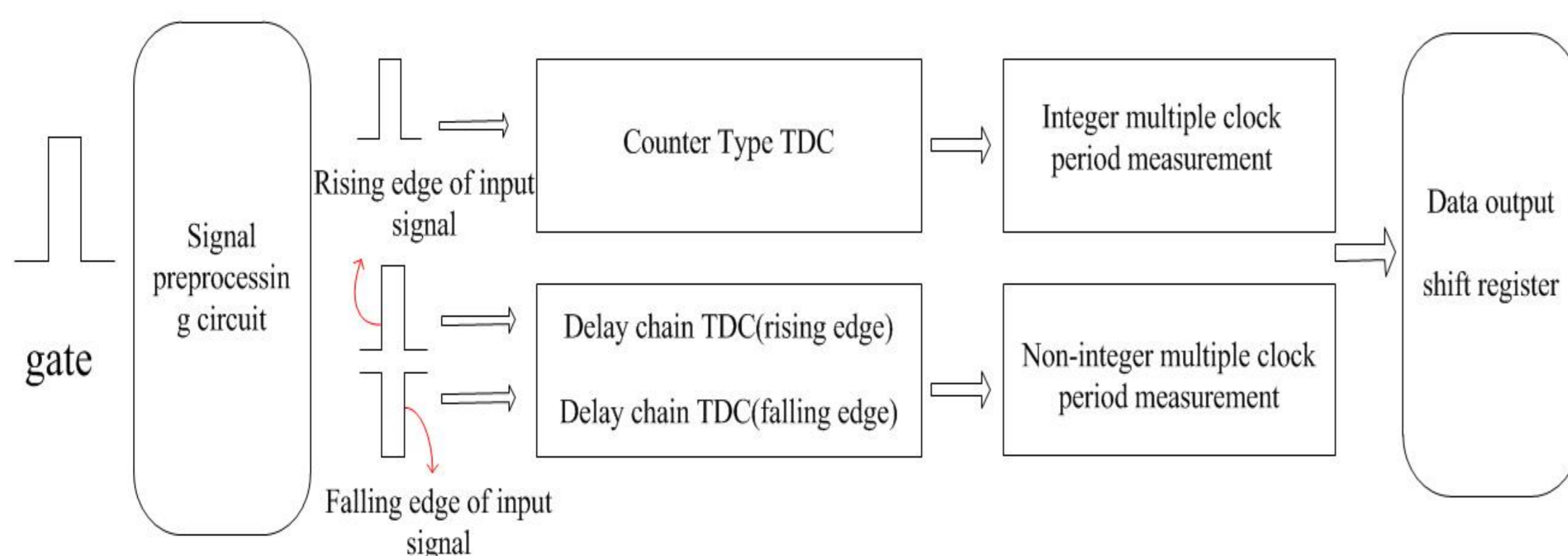


Figure 7. Structure of the Two-step TDC circuit

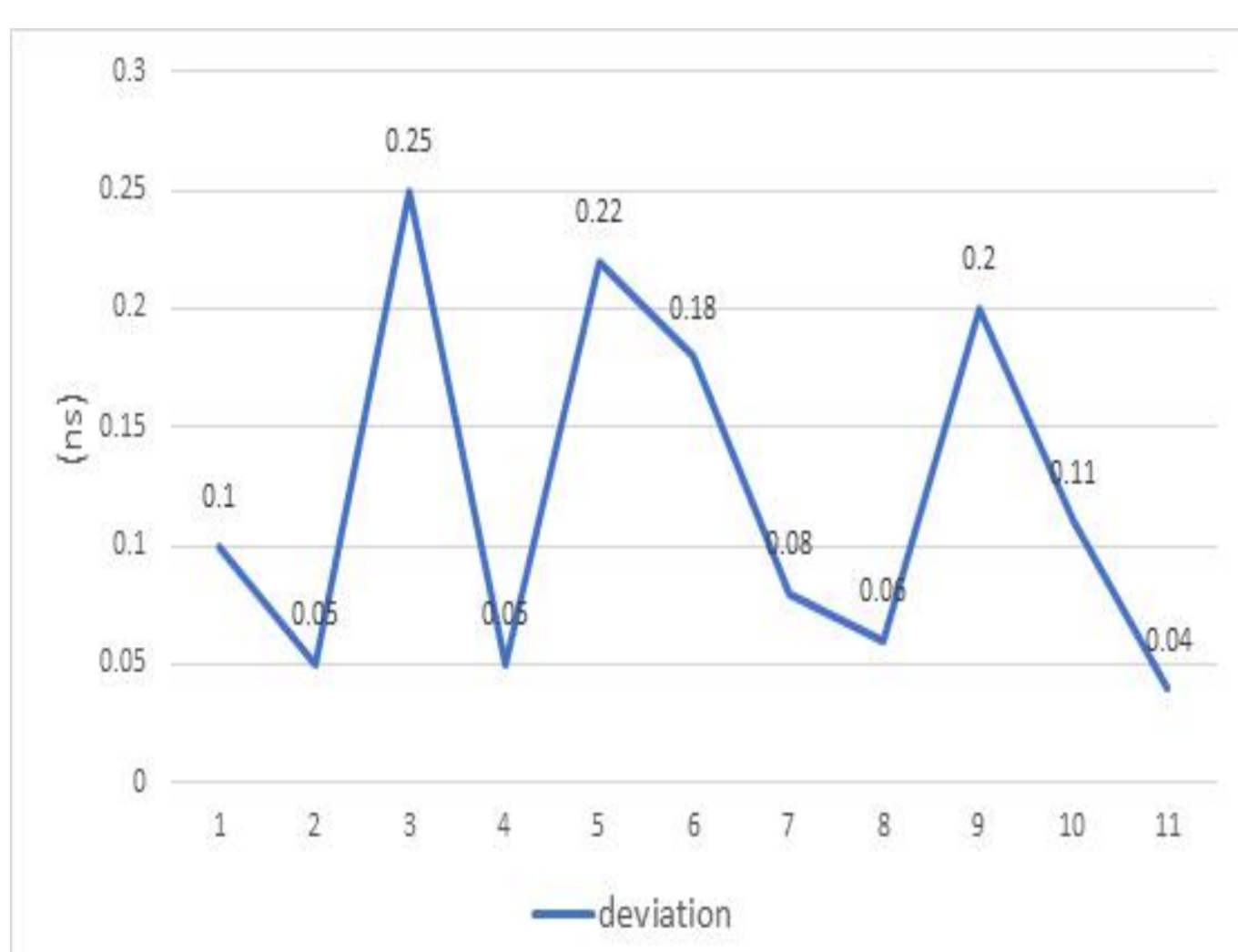


Figure 8. DNL post-simulation results of the Two-step TDC

The new two-step TDC is shown in Figure 7. It is designed to improve the time resolution. Figure 8 shows the post-simulation results of the two-step TDC circuit. The results show that the resolution of the TDC can be up to 70 ps, the dynamic range is 640 ns, and the RMS is about 3 ps.

## Layout of the SICCC1

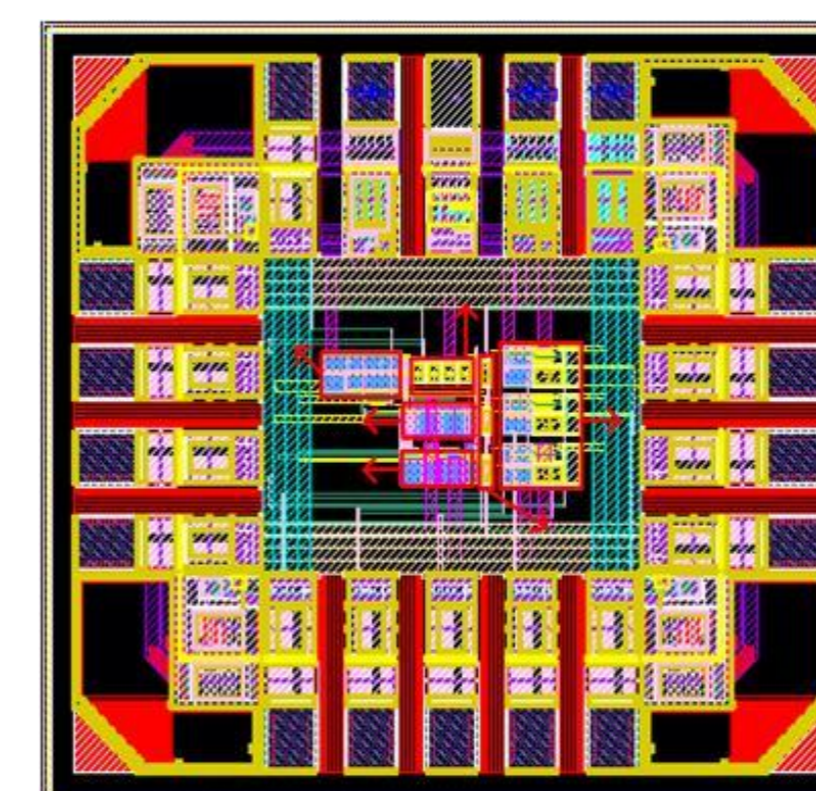


Figure 9. Layout of the SICCC1

- ◆ The SICCC1 is also fabricated in 130nm CMOS technology
- ◆ The dimension of SICCC1 is 1.065mm x 0.960 mm

## Conclusion

Both of the SICCO and SICCC1 use the traditional readout structure, including two readout path, one path uses TDC to record the arrival time and the other path uses front-end and ADC to detect the energy. The test results of the SICCO chip is as expected. To improve the time resolution, a new two-step TDC is designed on chip SICCC1. The post simulation results show that the resolution of the TDC is 70 ps, the dynamic range is 640 ns, and the RMS is about 3 ps. The SICCC1 chip is still under testing now and the optimization of the chip is also ongoing.