

## An Analog-Digital Hybrid Fine Interpolation TDC with Uncontrolled Delay Lines and Calibration Approaches

With the development of physics experiments, many detectors utilize the time-to-digital(TDC) to achieve a high-precision Time-of-Arrival(ToA) measurement. An analog-digital hybrid fine interpolation TDC is proposed to achieve high time precision in this paper. The TDC consists of an analog-digital hybrid fine interpolator and a digital module. The analog-digital hybrid fine interpolator is composed of an uncontrolled delay line, switches and source followers. The uncontrolled delay line has a simple structure, finer measurement precision and various methods to calibration. For every incoming hit, the START signal transmits through the delay line. Once the STOP signal arrives, the switch is off and the analog voltage at each delay unit is sampled by the parasitic capacitor. The analog voltage can provide finer time precision. The fine time information is captured by the analog fine interpolation and the digital fine interpolation. A digital module provides the results of encoding, meanwhile controlling the switch to transfer the analog voltage through a source follower to an off-chip flash ADC.

Since the propagation delay of each delay cell is not known and also varies at different temperatures and power supply voltages, some calibration approaches are proposed. By injecting two known time-interval signals, the rising and falling time of the inverter can be estimated, while a calibration lookup table is produced. Meanwhile, an extra inverter adds at the end of the delay line to characterize the transformation of the source follower.

The TDC ASIC features a size of  $1300\mu\text{m} \times 1200\mu\text{m}$  with 29 pads fabricated in a TSMC  $0.18\mu\text{m}$  process. The TDC is driven by a 330MHz, that is the fine interpolation is within 3ns. The simulations show the conversion rate is up to 30MHz and the precision is 5ps. The test is undergoing and the results will be reported in the conference.

### Submission declaration

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**Author:** YANG, Yichen (Institute of modern physics, Chinese Academy of Sciences)

**Co-authors:** Dr YOU, Bihui; Prof. GAO, Chaosong; Mr LIU, Jun; Ms QIAO, Yuxin; Mr HU, Zhengyu; Prof. SUN, Xiangming; Prof. HUANG, Guangming; Dr WU, Tianya (Chinese Academy of Sciences (CN))

**Presenter:** Dr WU, Tianya (Chinese Academy of Sciences (CN))

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