Low Precision Particle Detection

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**Background**

- High-speed timing systems are the key component of any particle accelerator. However, while many precision timing systems can perform the task, they are often expensive. Projects like CERN’s Mathusla detector need thousands of timing systems and would require a substantial budget if current price detectors are used. Therefore, it is necessary to develop a low-cost precision timing system from commercially available parts.
- To detect the path of rare particles, layers of detectors will be constructed on top of the experiment site. The points at which the particle interacted with the detector are timed and then used to map its path. (See diagrams)

**Experimental Setup**

- Low Noise Preamplifier
- Oscilloscope
- Waveform Generator, triggered by divided signal
- Power Supply
- Tunable Bandpass Filter
- Clock Generator, set at 100 MHz
- Dividers
- Trombone
- Low Pass Filter
- Mixer
- 10 Hz Attenuator
- Coaxial Amplifier

**Simulation Results**

- In signal
- rf signal
- mixer
- filtered in signal
- filtered signal

**Experimental Prototype**

To create a mixed signal, a fast clock signal needs to be mixed with an external pulse. The fast clock signal comes directly from a clock generator that is set to output a 100 MHz signal. The pulse is created by dividing the fast signal by four 4-bit counters by 2⁴, which triggers a waveform generator generating a pulse. The pulse goes through a tunable bandpass filter to transform the pulse into a ringing sine wave (for better results from the mixer), and then a trombone to test the sensitivity of the mixed signal to pulse delay. Lastly, both signals are then mixed, put through an 11 MHz low pass filter and a preamplifier for readability, and are then displayed on the oscilloscope.

**Pulse Mixing**

The 100 MHz clock was successfully mixed with a divided signal with an average precision of 72 picoseconds. Using a two-output set up an average precision of 42 picoseconds was reached. Microchip: LED's delay response to a change in resistance shows the ADC conversion with an external trigger. Printing the results of the ADC proved to be difficult. Texas Instruments: Read and printed the ADC's conversion of an external voltage source at a hundred thousand samples per second. External hardware triggering however, proved to be difficult.

**Results**

**Conclusions**

**Problems:**
- The mixed signal was readable, but there is noticeable timing jitter.
- Could not find a way to both get a readout and externally hardware trigger the ADC.

**Improvements:**
- Research and implement a different microchip.
- Design and test the system for timing to ~20 nanoseconds, then 1 nanosecond.
- Trigger ADC using an external source.
- Use evaluation boards more suitable to high frequency signals.
- A two-output mixed signal was set up along with a replacement 14-bit counter instead of four 4-bit counters. At first glance the second system seemed to perform better. However, more testing needed to be done with this setup.

**Acknowledgments**

Eric: I’d like to thank Don Williams for the consistent support throughout my STEM education as well as Joe Frisch and Scott Block for this experience.

Chengcheng: I’d like to thank Charlie Chengcheng and John Doulakio giving me this internship opportunity.

Sasha: I’d like to thank Joe Frisch for giving me this internship opportunity.

The 2019 STEM Teacher and Researcher Program and this project have been made possible through support from Chevron (www.chevron.com), the National Science Foundation through the Robert Noyce Program under Grant #1836335 and the California State University Office of the Chancellor and California Polytechnic State University in partnership with SLAC. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the funders.