FPGA Implemented on TDC: Improving its Resolution

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Keywords

- FPGA
- TDC
- Improving Resolution
Keywords

FPGA

- Field-Programmable-Gate-Array
Keywords

TDC

- Time-to-Digital-Converter
- Electronic instrument
- Converts events, time → digital representation
- Measures time interval
What are some possible causes of delay and how can high-resolution TDC be implemented in FPGA?
Analogy for Time delay

20ns

Gate

A

B
Flow Diagram of Data Collecting Process

Start → Pulse Generator

Wire 1 → Tektronix Oscilloscope → TDC implemented in FPGA

Wire 2 → 20ns delay

TTree.h → ROOT

TDC_Trial1.txt → TDC_DeltaT1.c

Collect raw data

Histogram.jpg
Tektronix 640S

Introduction - Methods - Discussion - Conclusion - Future Work - Appendix
TDC Implemented on FPGA

- TDC implemented on FPGA
- Logic Fan
8 and 12 indicate the gate number
C = 12 in hexadecimal
1500 ~ 2000 hits
```cpp
#include <TTree.h>
#include <TCanvas.h>
#include <TStyle.h>

void DNLPPlot1()
{
    gROOT->Reset();

    TTree *MyTree = new TTree("MyTree","analyseddata");
    MyTree->ReadFile(data3.txt,"TBin1:ch2:Nevt:Nevt2");
    TCanvas *c1 = new TCcanvas();
    TH1F *TestPic = new TH1F("TestPic","TDC DNL",256,0,256);
    MyTree->Draw("TBin1>>TestPic");

    //MyTree->Draw("hits");
}
```

- Set x bound
- Title, legend
Flow Diagram of Data Collecting Process

Start

Pulse Generator

Wire 1

No Delay

Tektronix Oscilloscope

TDC implemented in FPGA

Collect raw data

Wire 2

20ns delay

TTree.h

TDC_Trial1.txt

TDC_DeltaT1.c

ROOT

Histogram.jpg
Results

Time Difference 20 nsec

**TestPic**

<table>
<thead>
<tr>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1477</td>
<td>22.39</td>
<td>0.0771</td>
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</table>

Time Difference 20 nsec

**TestPic**

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Discussion

- environmental factors
  - Heat
    - 0°C to 80°C
    - Doesn’t vary much
  - Voltage
    - ±5% of normal supply voltage
Application

- PET Scan
- Radioactive Isotopes
  - Carbon-11 (20min)
  - Nitrogen-13 (10min)
  - Oxygen-15 (2min)
  - Fluorine-14 (<2hr)
- Emit gamma rays
- (emit positrons when they decay)
Application

- High resolution TDC
- Detectors
- Can have more accurate location
Conclusion

- Resolution of 80ps
- Environmental factors
- Device quantization error
- Event $\rightarrow$ Binary Code
Future Work

- Resolution better than 60ps
- New architectural design configuration
- Efficient program to generate data
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Questions?
Question

- MRI
  Anatomic imaging
- PET
  how organs and tissues function
  Evaluate medical condition