Catching Sudden Beam Loss with Red Pitaya

Abhinandan Tiwari

Indian Institute of Technology Guwahati

July 23, 2025

Introduction

Name - Abhinandan Tiwari

Raipur, Chhattisgarh – My hometown in central India

IIT Guwahati – One of India’s top engineering institutes

Currently in my 4th year of Engineering Physics, exploring the intersection of electronics and physics

INDIA
States and Union Territories
TAJIKISTAN
AFGHANISTAN
PAKISTAN
CHINA (TIBET)
NEPAL
BHUTAN
BANGLADESH
MYANMAR (BURMA)
SRI LANKA
LADAKH
Leh
Srinagar
JAMMU & KASHMIR
Jammu
HIMACHAL PRADESH
Shimla
PUNJAB
Chandigarh
Dehradun
UTTARAKHAND
HARYANA
DELHI
New Delhi
UTTAR PRADESH
Lucknow
Jaipur
RAJASTHAN
SIKKIM
Gangtok
Itanagar
ARUNACHAL PRADESH
Dispur
ASSAM
NAGALAND
Kohima
Shillong
MEGHALAYA
Imphal
MANIPUR
Agartala
TRIPURA
Aizawl
MIZORAM
BIHAR
Patna
JHARKHAND
Ranchi
WEST BENGAL
Kolkata
Gandhinagar
GUJARAT
Bhopal
MADHYA PRADESH
Raipur
CHHATTISGARH
ODISHA
Bhubaneswar
Daman
Silvassa
DAMAN & DIU
DADRA & NAGAR HAVELI
MAHARASHTRA
Mumbai
TELANGANA
Hyderabad
Amaravati
Yanam (Puducherry)
ARABIAN SEA
BAY OF BENGAL
Panaji
GOA
KARNATAKA
ANDHRA PRADESH
Bengaluru
Chennai
PUDUCHERRY
Mahe (Puducherry)
Kavaratti
LAKSHADWEEP (INDIA)
KERALA
TAMIL NADU
Karaikal (Puducherry)
Thiruvananthapuram
Palk Strait
Port Blair
ANDAMAN & NICOBAR ISLANDS (INDIA)
International Boundary
State/UT Boundary
Country Capital
State/UT Capital
Map not to Scale
INDIAN OCEAN
Copyright © 2019 www.mapsofworld.com

What I’m Working On

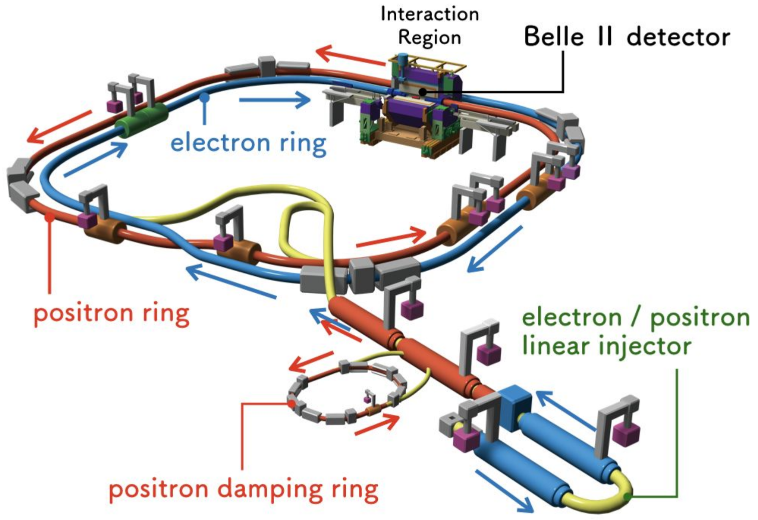
Mentor - Hiroshi Kaji

Problem: Sudden Beam Loss (SBL) events damage the accelerator

- In recent SuperKEKB operation, an increasing number of sudden beam loss events have been observed, in which a portion of the stored beam is suddenly lost.
- Some of the larger beam loss events caused serious damage to the collimators and Belle II sensors.

Goal: Detect large beam loss quickly and trigger interlock to abort beam

- When the large beam loss is detected in the accelerator, the beam is in the dangerous condition.
- Therefore, the beam loss monitor launches the interlock signal in such case. Then, we quickly throw the beam to the beam dump (we call it beam abort!).



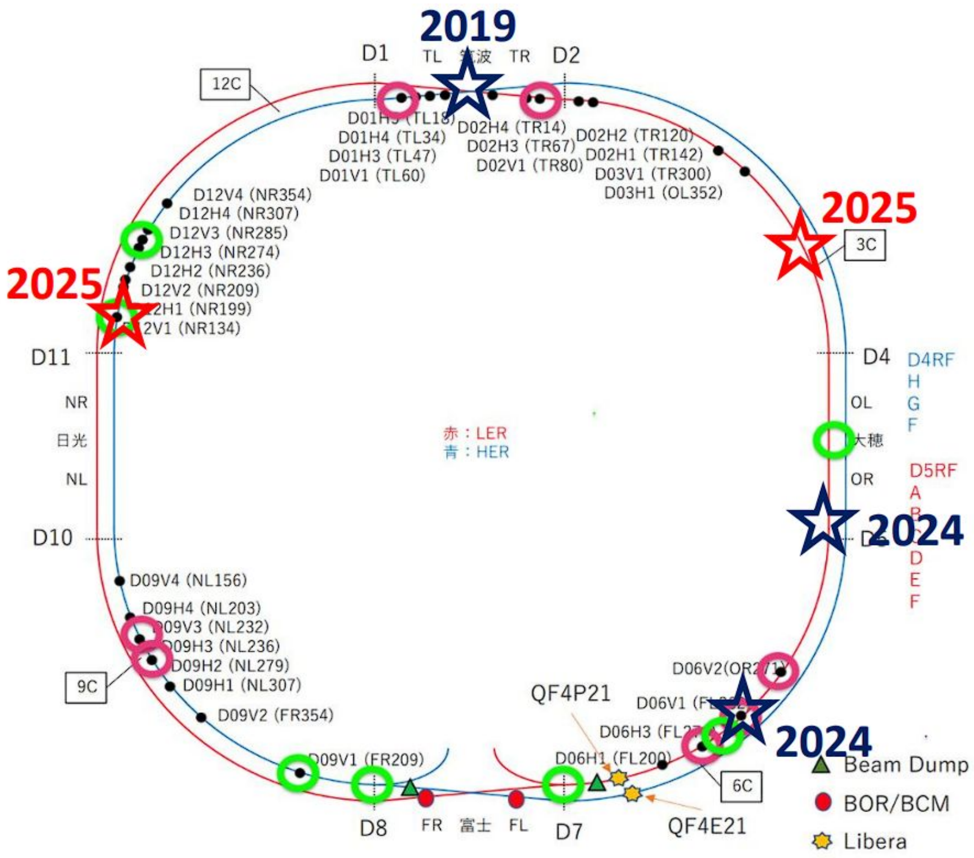
Installation of Abort Sensors

What is an abort sensor?

An abort sensor is a device that constantly monitors the particle beam. If it detects something wrong (like the beam drifting or hitting the accelerator wall) it immediately triggers an "interlock", which kills the beam to prevent damage.

Why install more sensors now?

- Beam accidents (SBLs) are happening almost daily.
- Faster detection = faster abort = better protection for the accelerator.
- More sensors placed along the beam path help catch issues earlier, especially when beam current is high.



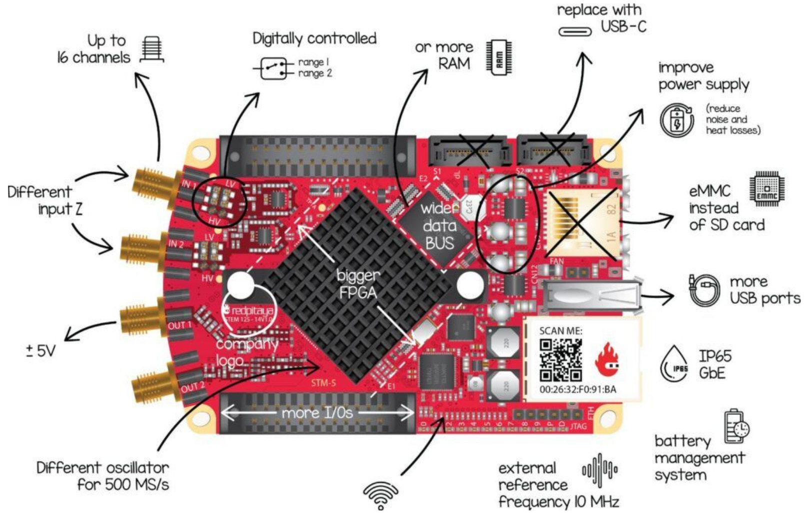
Developing a Fast Interlock Launcher using Red Pitaya

1. Problem: Old System Too Slow & Obsolete

- Previous systems (e.g., Keysight, Picoscope) are End-of-Life (EoL)
- High latency (360–400 ns) = delayed beam abort response
- Not ideal for handling Sudden Beam Loss (SBL)

2. Solution: Red Pitaya-based Launcher

- Developing a new launcher circuit using Red Pitaya
- Target latency < 100 ns
- Fully programmable, open-source, and cost-effective
- Already in use at other KEK facilities (like ATF)

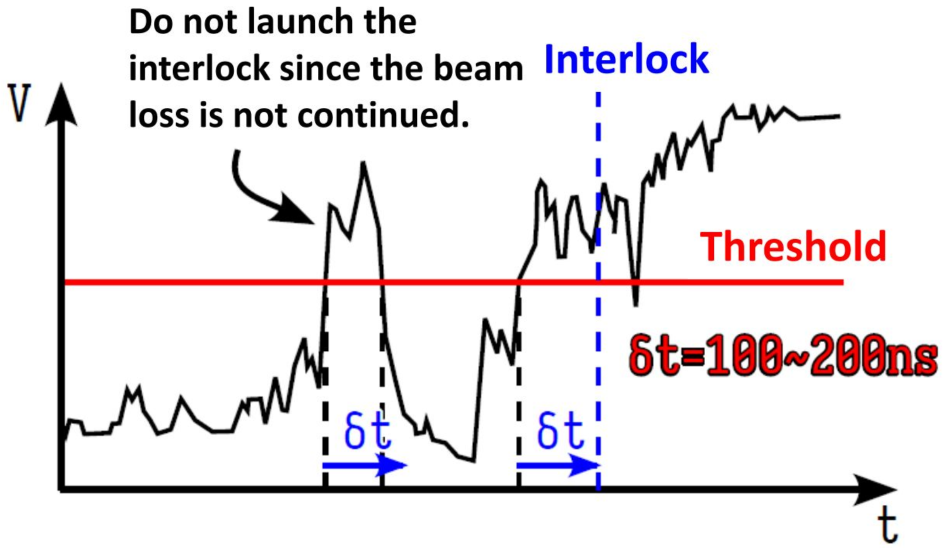


Interlock Condition

The interlock triggers only when both:

- The beam loss signal exceeds a voltage threshold
- The signal lasts 100–200 ns or more

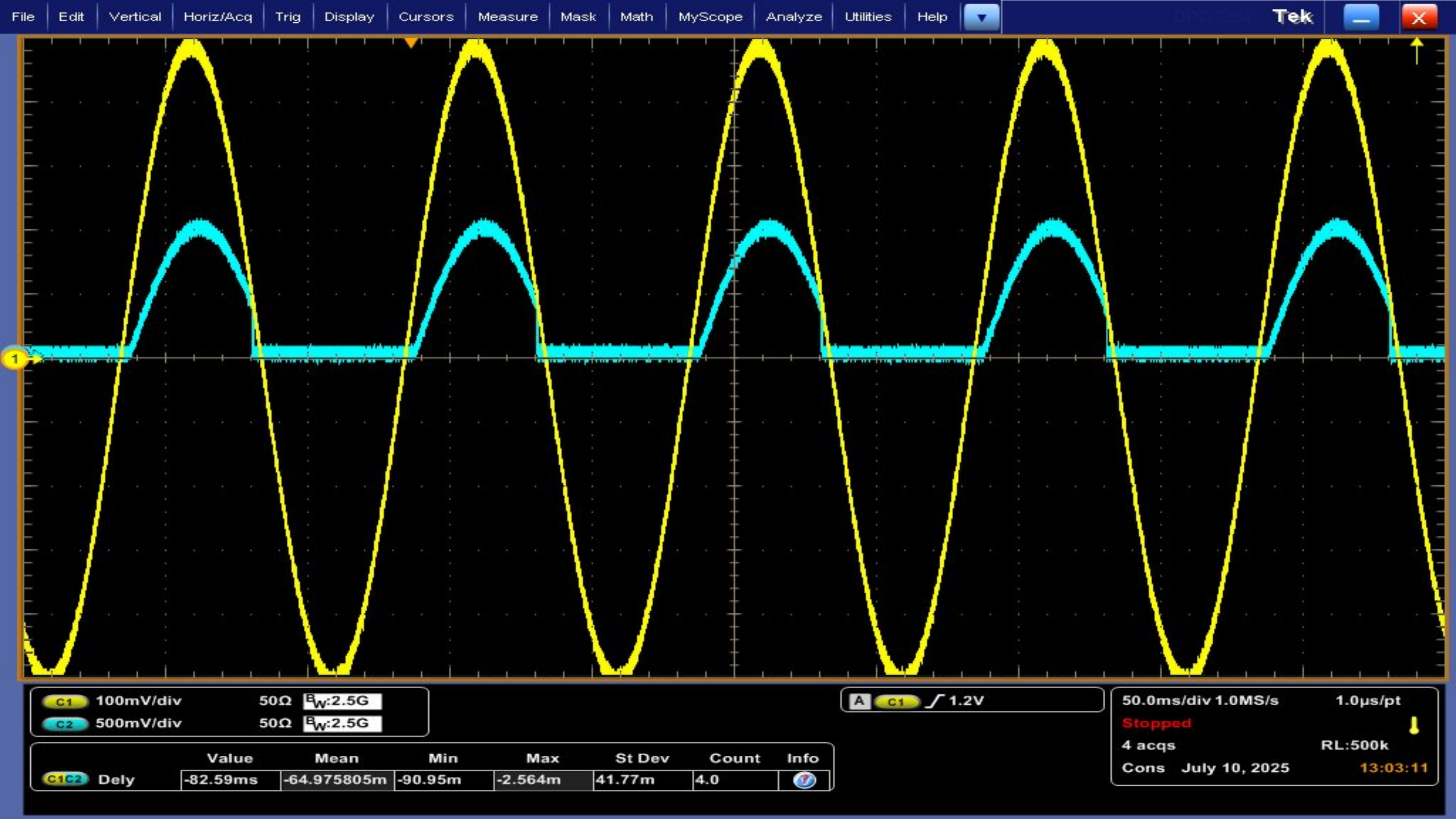
This ensures we ignore short spikes (noise) and only react to real beam failures



Do not launch the interlock since the beam loss is not continued.
Interlock
V
Threshold
δt=100~200ns
δt
δt
t

My Progress So Far

- Developed interlock logic to trigger an output pulse when the input signal crosses a 100 mV threshold
- Achieved a minimum latency of ~25 µs using Red Pitaya
- Learned to generate custom RF signals with configurable frequency, amplitude, and phase.
- Learned to acquire and process input signals, including threshold-based detection.
- Hands-on with Red Pitaya APIs: working with low-level signal handling, triggering logic, and waveform analysis

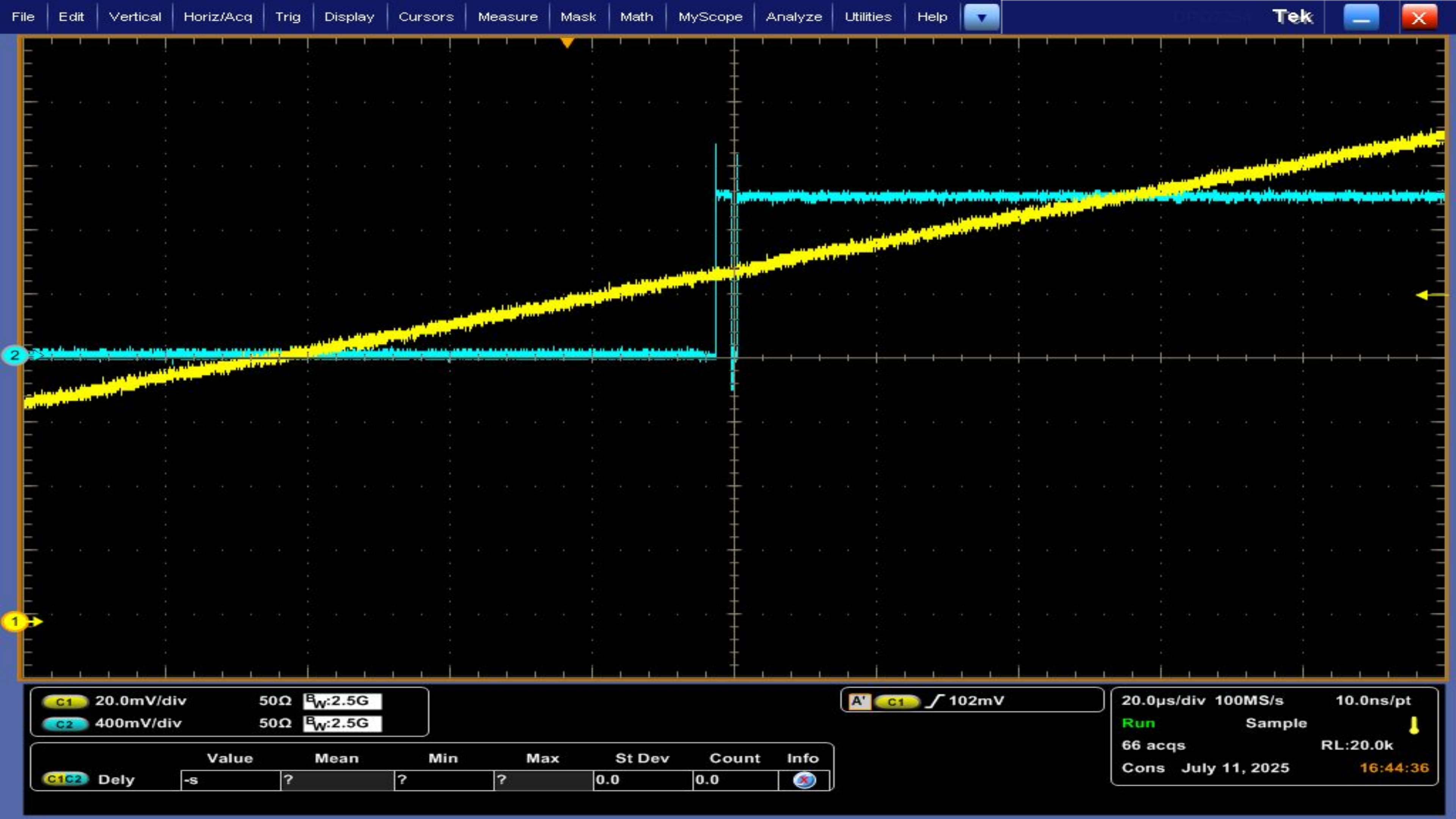


```
C1  100mV/div   50Ω  BW:2.5G
C2  500mV/div   50Ω  BW:2.5G
```

```
A  C1  ∫ 1.2V
```

```
50.0ms/div 1.0MS/s      1.0µs/pt
Stopped
4 acqs                  RL:500k
Cons   July 10, 2025    13:03:11
```

		Value	Mean	Min	Max	St Dev	Count	Info
C1C2	Dely	-82.59ms	-64.975805m	-90.95m	-2.564m	41.77m	4.0	



C1 20.0mV/div 50Ω BW:2.5G
C2 400mV/div 50Ω BW:2.5G

A' C1 ⨍ 102mV

20.0µs/div 100MS/s 10.0ns/pt
Run Sample
66 acqs RL:20.0k
Cons July 11, 2025 16:44:36

	Value	Mean	Min	Max	St Dev	Count	Info
C1C2 Dely	-s	?	?	?	0.0	0.0	

Future Work

- Optimize hardware and firmware to further reduce system latency, targeting sub-microsecond (<1 μs) response times.
- Build a custom SD card image optimized for low latency
- Design custom FPGA modules for real-time threshold detection and output generation for ultra low latency operation (100-200ns)

THANK YOU!