Evaluating stretched TDC: Status Update

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Contents

1. Reminder: Stretched TDC Circuit

The goal

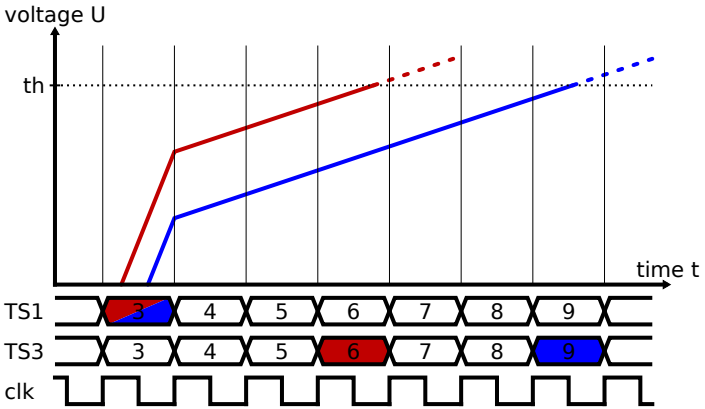
We want to measure particles

- improve precision of time measurements for hits
- that's it

Performance Metrics

- precise timing (ideally below 1ns)
- homogenous time resolution
- low variance between pixels
- try to keep power draw low if possible

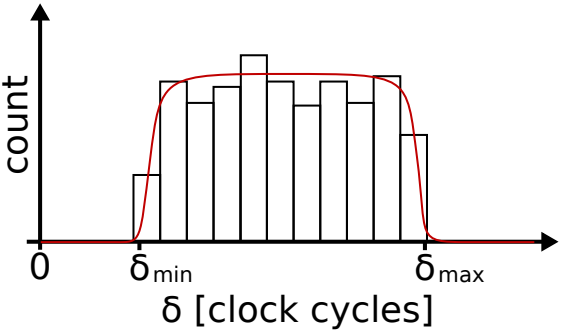
Idea: Stretched TDC



Expected outcome for the distribution of δ

- *TS3* should have a delay from *TS1* which distributed approximately evenly over a sharply defined range
- define $\delta := TS3 - TS1$
- define δ_{min} and δ_{max} as the edges of the distribution
- reconstruct $t_{hit} = clock\_period \cdot (TS1 + \frac{\delta - \delta_{min}}{\delta_{max} - \delta_{min}})$

Excpected distribution of δ over all hits



Fit the delta Distribution

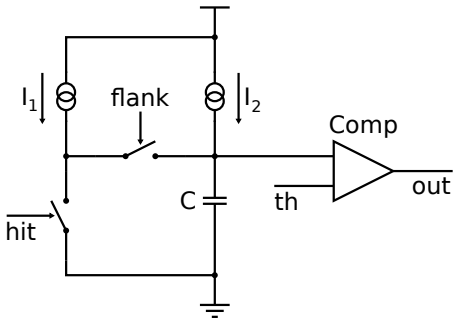
- A box function might sound natural but fits will likely fail due to the unsteady nature
- Instead as sigmoid function to approximate the edges of the block
- $sig(x; c, s) := \frac{1}{1+\exp(-4s(x-c))}$
- free parameters: edge position c and slope s
- full fit function: multiply two sigmoids
  $f(x; A, B, l, r, s_l, s_r) :=$
  $B + A \cdot sig(x; l, \frac{s_l}{A}) \cdot sig(x; r, \frac{s_r}{A})$

Sigmoid curve and full fit function missing :)

Implementation: Stretched TDC circuit

- By default pull voltage at the capacitor to *GND*
- Once a hit is registered, disconnect the connection to ground such that the current supplies I_1 and I_2 charge the capacitor
- Once the clock edge hits, disconnect I_1, such that now only I_2 charges the capacitor
- Once the threshold is passed, store the current value of *TS3*

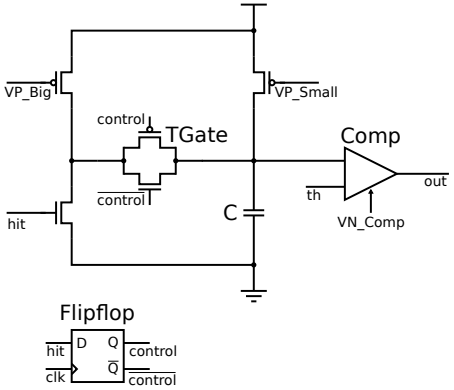
Simplified model of the *stretched TDC* circuit



Implementation: Stretched TDC circuit

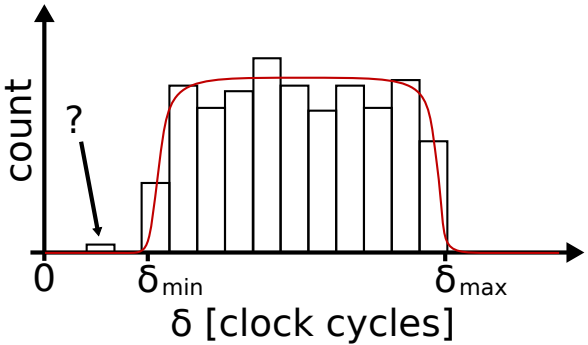
- For current sourche use pmos transistors in saturation, control the current with DAC values (*VP_Big* and *VP_Small*)
- The connection to ground is regulated using an NMOS transistor
- The connection of I_1 to the capacitor is regulated using a transmission gate
- Use a Flipflop for the transmission gate input, such that is changed once the clock edge hits but only if a hit is there 0AC values to select are
- Two more DAC values for *th*reshold and *VN_Comp*

Transistor level model of the *stretched TDC* circuit



Problem: Stray values for δ

How do we interpret timestamps with delta outside the range $[\delta_{max}, \delta_{min}]$?



Depends on what the cause is...

Problem: Manufacturing variance

- There is some pixel-by-pxel variance in transistor parameters and (more importantly) C
- We need to individually find δ_{max} and δ_{min} for each pixel to calibrate the time reconstruction

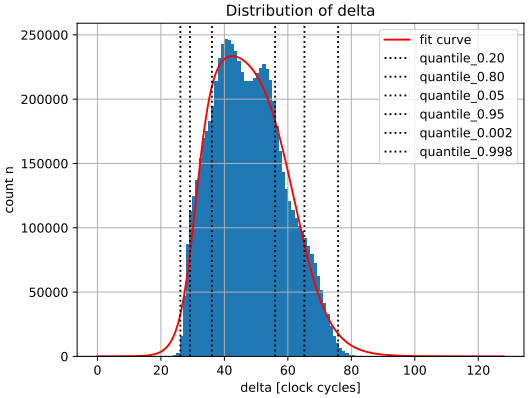
2. Results: Stretched TDC Analysis

Measurement setup

- I did runs for a lot of parametric selections, but for now look at just 2 of them
- Slow and precise: $VP\_Big = 8$, $VP\_Small = 8$, $VN\_Comp = \text{a}$, $th = 1300\text{mV}$
- Fast and tight $VP\_Big = \text{a}$, $VP\_Small = \text{c}$, $VN\_Comp = \text{a}$, $th = 1300\text{mV}$

Global delta distribution

$VP\_Big = 8$, $VP\_Small = 8$, $VN\_Comp = \mathrm{a}$, $th = 1300\mathrm{mV}$



Global delta distribution

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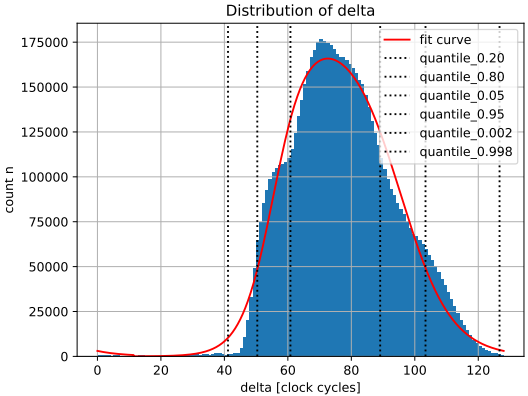

Single Pixel delta distribution

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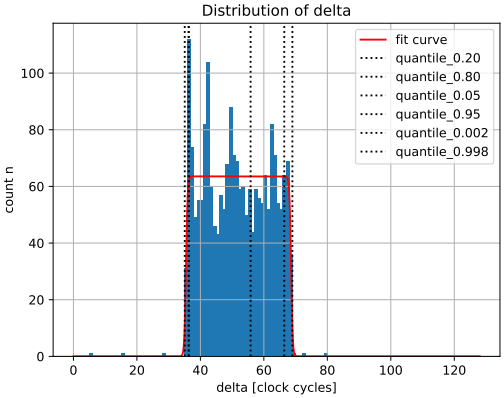

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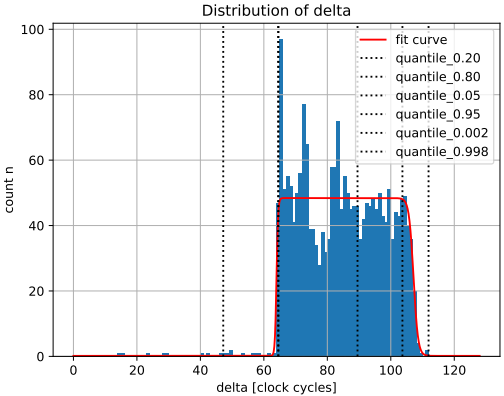

How many stray timestamps are there?

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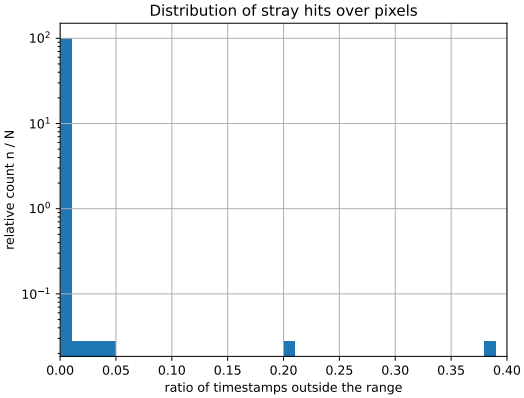

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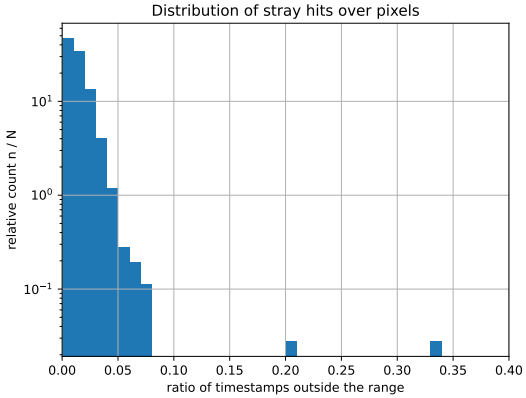

Do stray timestamps correlate with δ_{max}?

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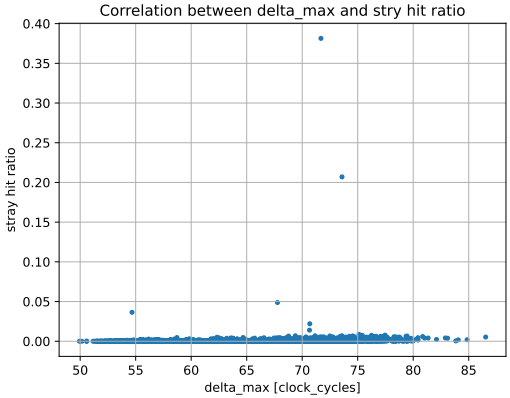

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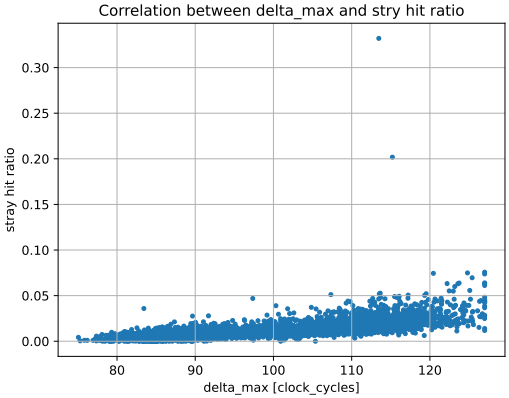

Do stray timestamps correlate with amount of hits (hot or dead pixels)?

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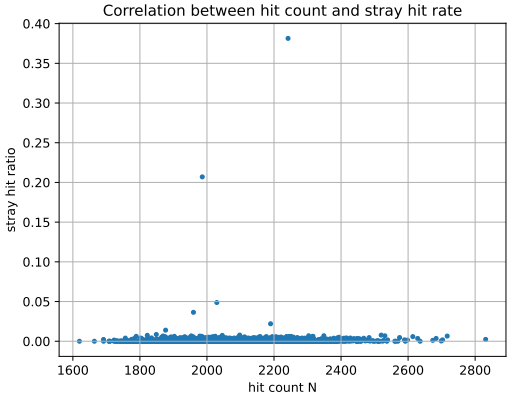

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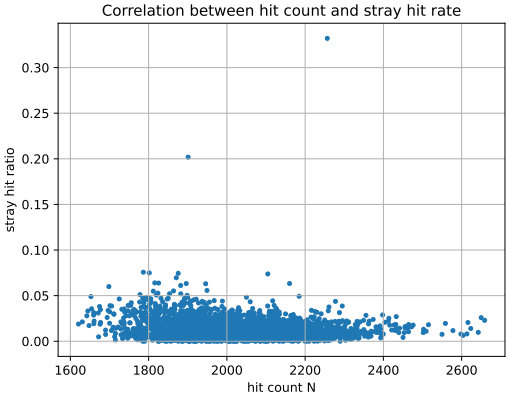

Distribution of δ_{max} and δ_{min} over all pixels

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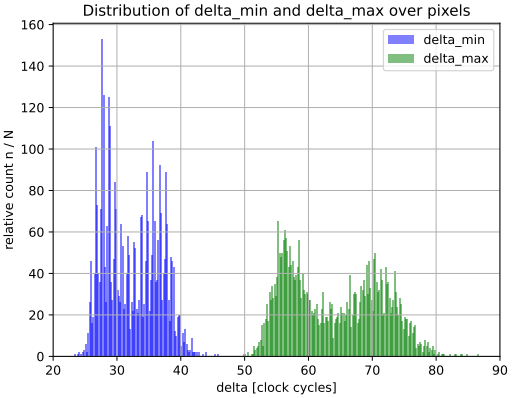

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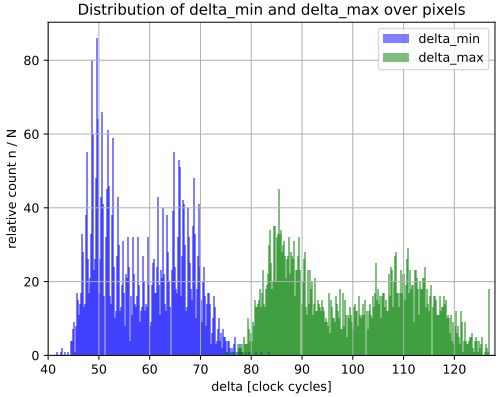

Distribution of block width $w := \delta_{max} - \delta_{min}$ over all pixels

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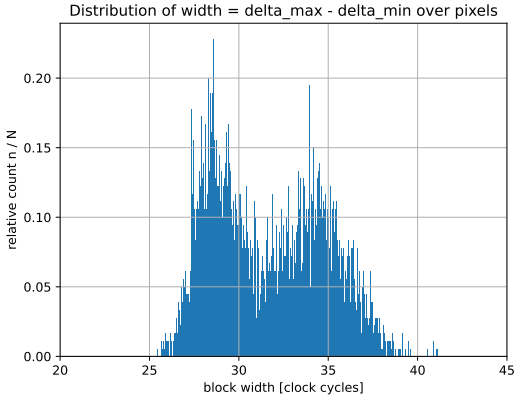

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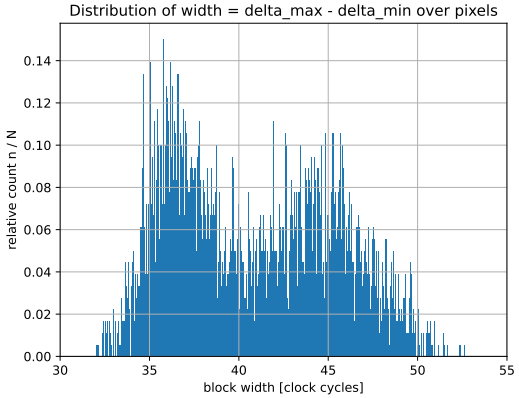

How does δ_{max} relate to δ_{min}?

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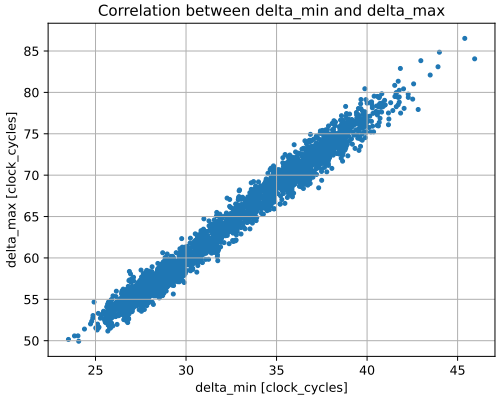

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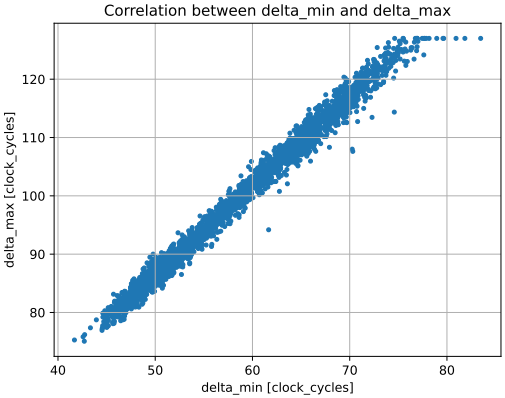

Up next

- See if there is correlation of fit results with pixel position on the chip (row, col)
- Do parametric analysis for DAC values
- Find the source of stray timestamps
- Find out which part of the circuit is influenced the most by manufacturing variance (I assume it is C)
- Any suggestions?