Double injection threshold scan for the RD53B

Thanks to Maurice Garcia-Sciveres, Timon Heim and Magne Lauritzen

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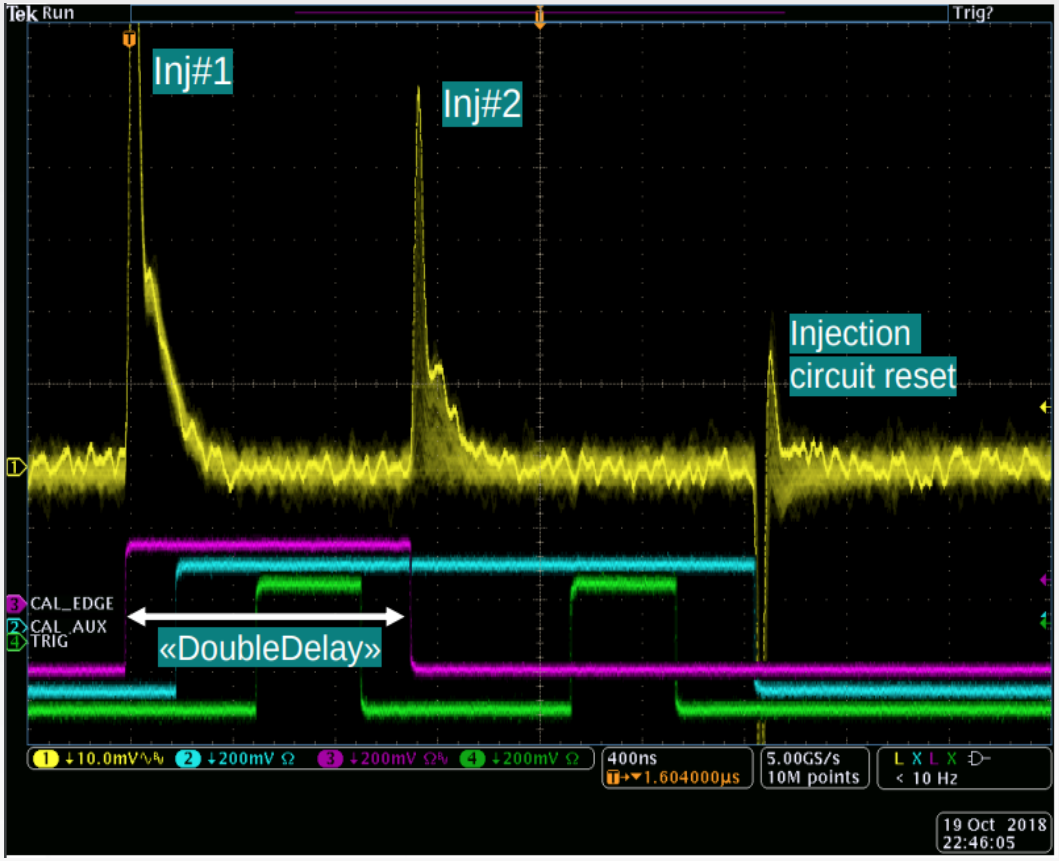
Introduction

- The purpose of the **double injection scan** is to study the behaviour of the Front-end (FE) during charge injections and data readout
- E.g. see how the measured pixel threshold is **affected** by a **preceding injection**
- **The double injection scan** can inject **two consecutive charge injections** into each pixel
  - Done via **Cal commands** which control the capacitor injections for a selected pixel
- **How it's done:**
  - First injecting a constant charge into the selected pixel (Inj#1)
  - Wait a set period (DoubleDelay [BX]) (1BX value = 25 ns)
  - Injecting a second charge of varying magnitude into the same pixel (Inj#2)
  - Send triggers to read out the data



Double injection scan taken by an oscilloscope. Figure by Magne Lauritzen

1) Purple line is the CAL_EDGE signal

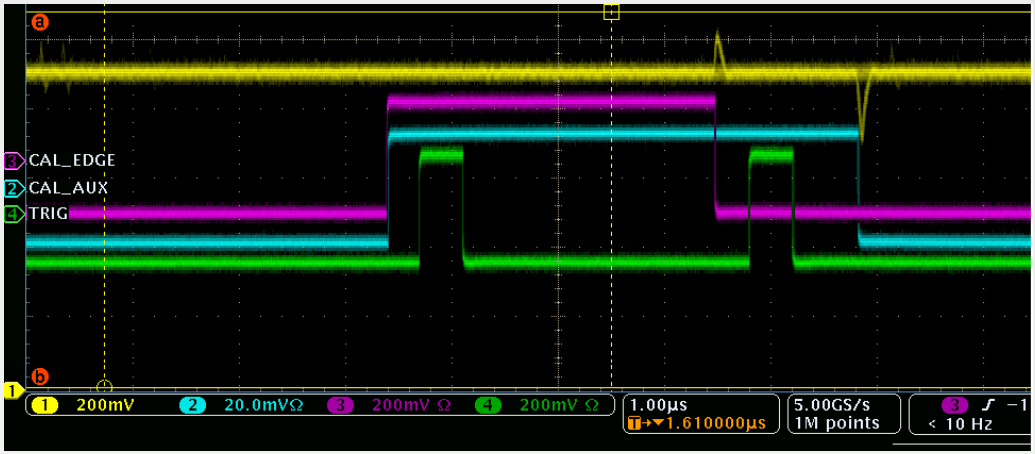
2) Light blue line is the CAL_AUX signal

3) Green line is the trigger signal

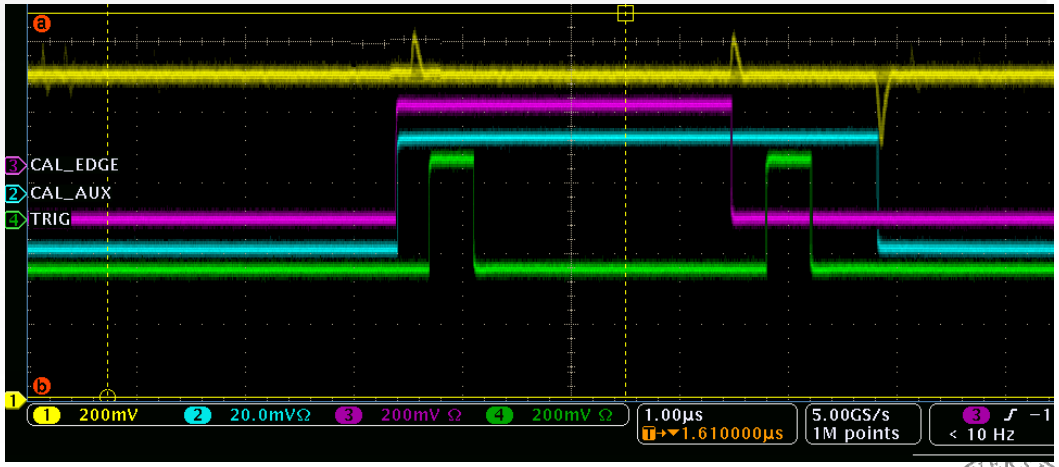
First Method

- Test the effect that a preceding charge injection has on the measured pixel threshold
- For each value of the double delay, perform:
  - A scan with **#Inj1 set to 0e** (Upper figure)
    - Gives a **baseline** threshold used for comparison
  - A double injection scan with a large **#Inj1** (Bottom figure)
    - **#Inj1** crosses the pixel threshold
- Calculate the mean of the pixel threshold difference between the baseline scans and the scans with a **#Inj1**
- **Probe** the effect that the **#Inj1** has on the measured pixel threshold

Baseline (Only have the second charge of varying magnitude)



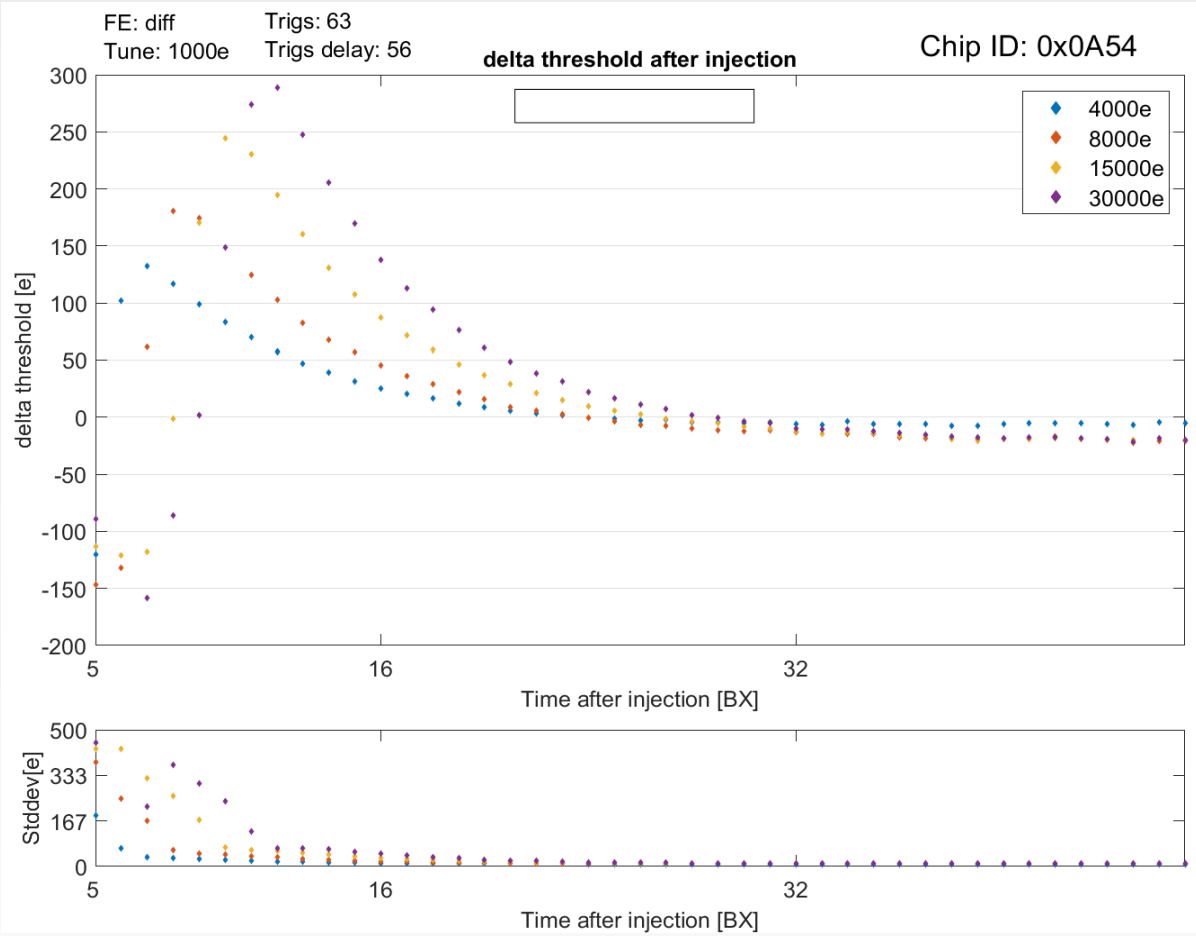
Large #1 injection and then inject a second charge of varying magnitude



Pre-Result: Mean of the pixel threshold differences vs. double delay

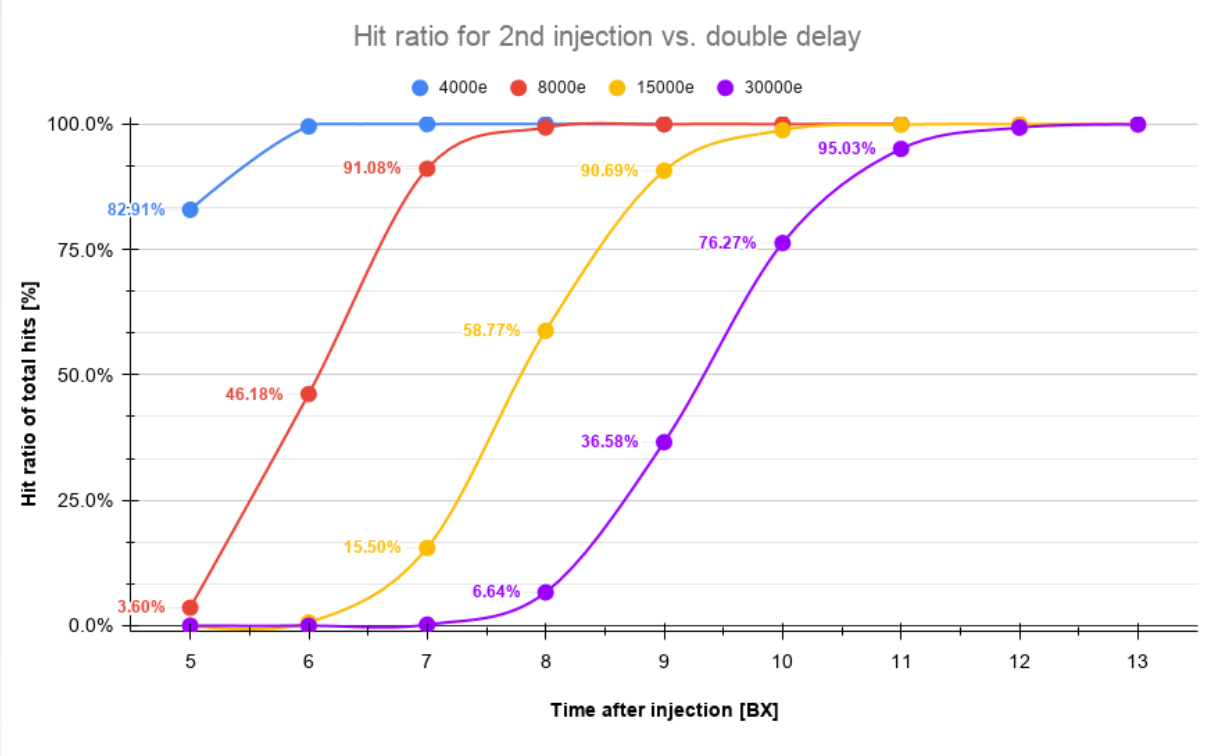
- Tuned with Vcal_Med = 230
- Colour code represents scans with different injection magnitude
- The maximum Δ threshold value increases with larger injections
- Threshold deviation goes up to:

  ~ 140e (4k), 190e (8ke), 250e (15k), 290e (30k) injections
- Maximum deviation point on each curve moves to higher double delay values for larger injections
- Δ threshold decreases exponentially after the maximum point
- 8-30ke injection gets a undershoot after 24 BX



Analysis on result: Hit ratio of the 2nd injection vs double delay

- Plotted the hit ratio of the second injection (threshold injection) at its maximum injection value (3200e)
  - Always be above threshold -> ~100%
- Observed: At low double delay values the hit ratio would decrease
- Hit ratio would be lower for larger injections
  - 30ke injection stays around 0% after 5-7 BX
- Effect due to the first injection staying above threshold at the second trigger
- Loose hits from the 2nd injection
- Artificially bias the S-curves and lead to lower measured threshold value
- Larger injection has longer ToT and thus this overlapping effect occurs for longer separations

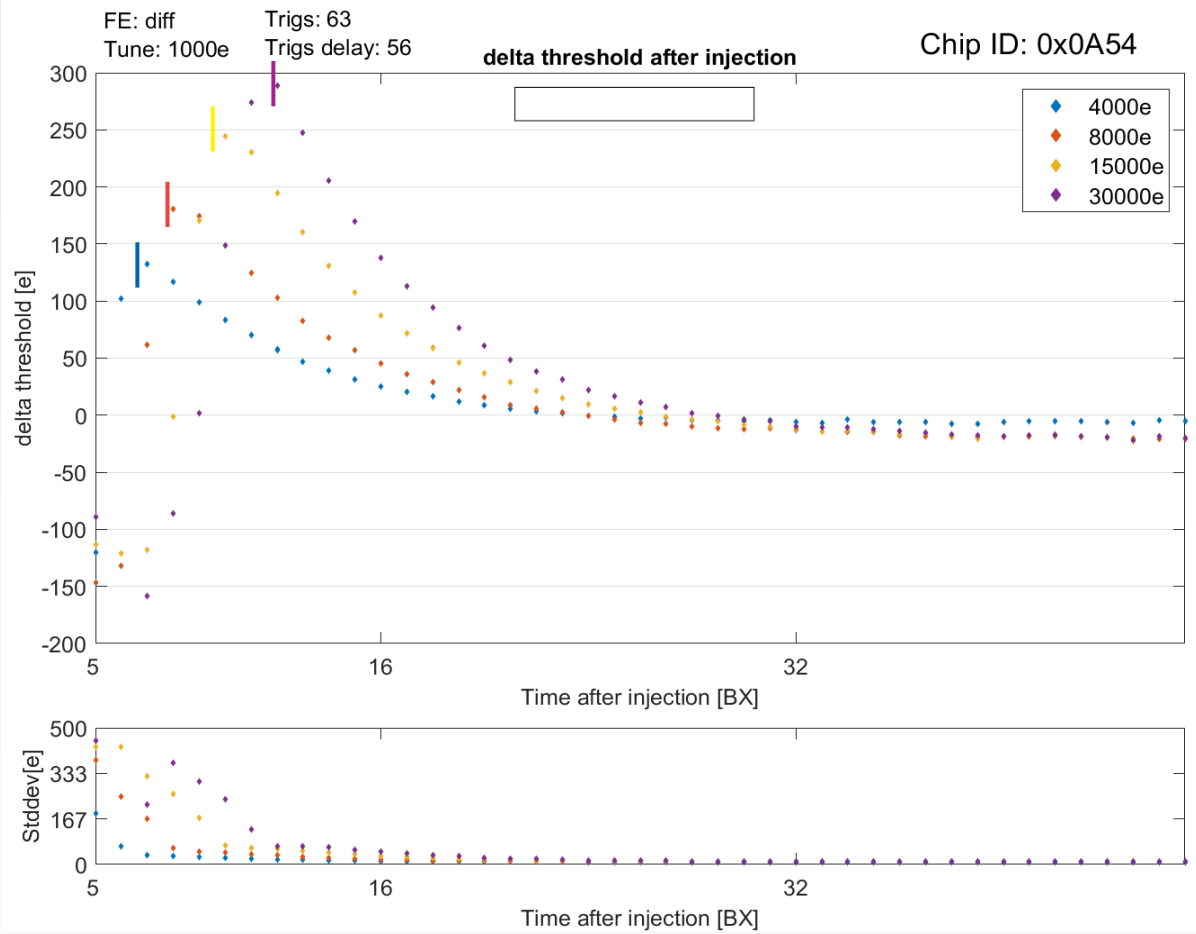


Re-visit: Mean of the pixel threshold differences vs. double delay

- Tuned with Vcal_Med = 230
- Colour code represents scans with different injection magnitude
- The maximum Δ threshold value increases with larger injections
- Threshold deviation goes up to:

  ~ 140e (4k), 190e (8ke), 250e (15k), 290e (30k) injections

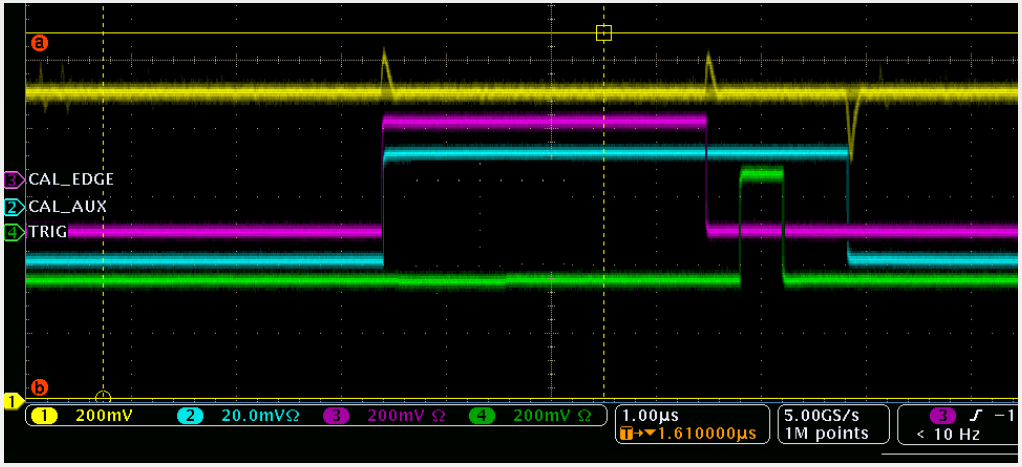
- Maximum deviation point on each curve moves to higher double delay values for larger injections
- Δ threshold decreases exponentially after the maximum point
- 8-30ke injection gets a undershoot after 24 BX
- Values below the maximum point on each curve is artificially low due to the overlapping of the first injection (see marker)



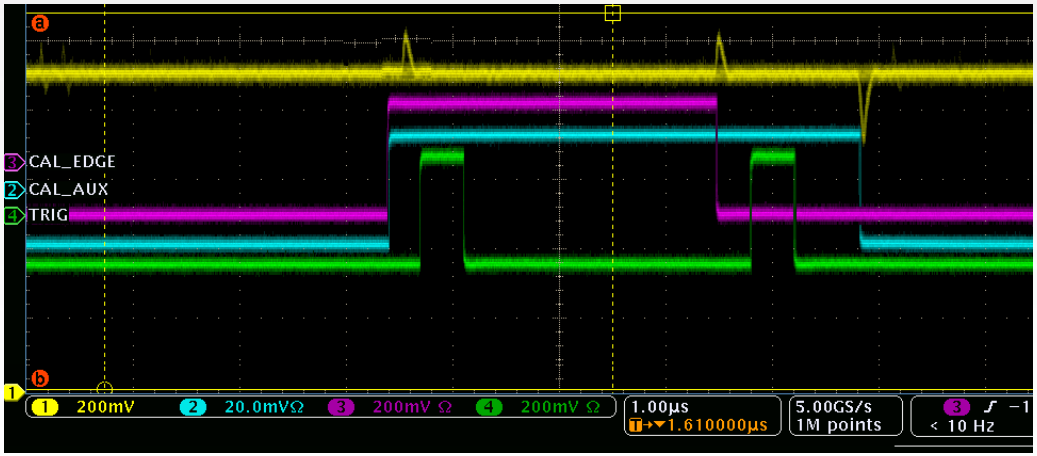
Second Method

- Test the effect that the readout has on measured pixel threshold
- For each value of the double delay, perform:
- A double injection scan with two injections but only the **second trigger** (Upper figure)
  - Gives a **baseline** threshold used for comparison
- A double injection scan (two trigger scan) with two injections and **two triggers** (Bottom figure)
  - **#Inj1** crosses the pixel threshold and is read out
- Mean of the pixel threshold difference between the baseline scans and the scans with two triggers
- **Probe** the effect that readout of the first injection has on the threshold distribution

Baseline (Only have the second trigger)

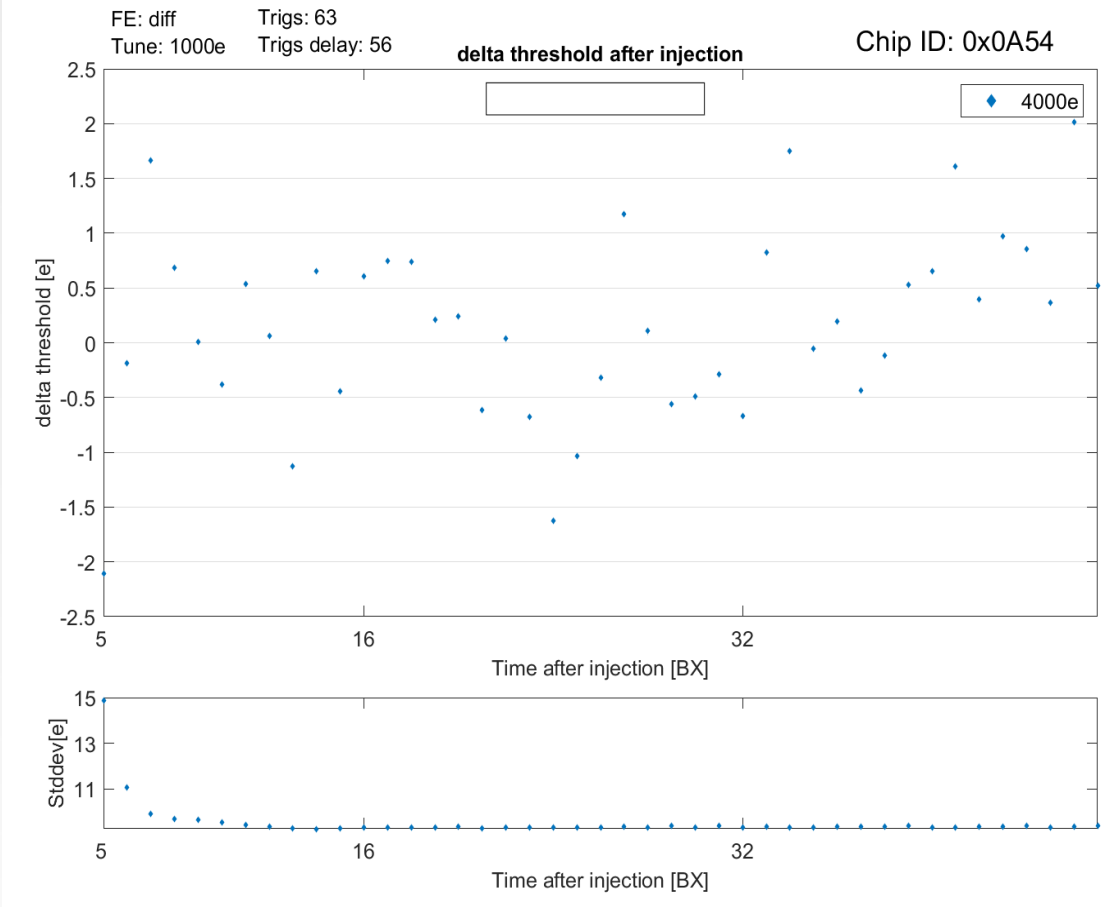


Two Triggers (Have two triggers so both injections are read out)



Result: Mean of the pixel threshold differences vs. double delay

- Tuned with Vcal_Med = 230
- #1inj = 4000e - > Above threshold
- Blue points: Mean of the pixel threshold difference between the two trigger scan and baseline scan
- Random small fluctuations around Δ threshold = 0e - > No difference observed
- No deviation observed from readout of the first injection



Conclusion

- A double injection scan sends out two consecutive charge injections into a single pixel
- Test the effect that a preceding charge injection has on the measured pixel threshold and also test the effect of reading out this signal
- **Results:**
- Threshold mean increases after a preceding injection
- This threshold deviation increases with the magnitude of the preceding injection and with lower time separations
- The maximum deviation occurs at the lowest time separation with a 100% hit ratio (ToT of the first injection < time separation)
    - All BX values lower than this point gets artificially low due the overlapping of the injections
- Readout of the first injection had no effect on the threshold distribution measured
- **Future work:**
- More analysis and implement double injection scan into YARR

Thank you for your attention!

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Backup

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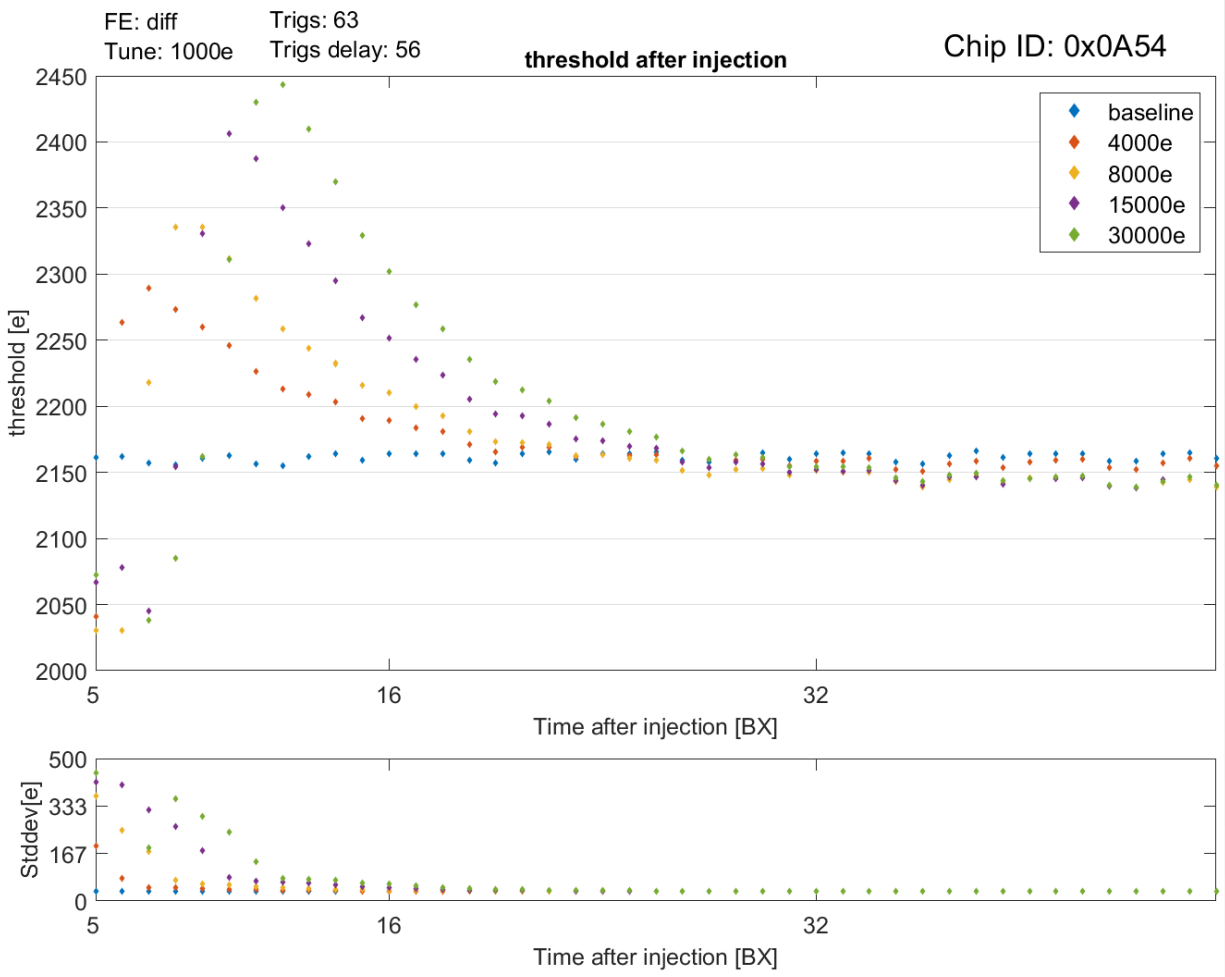
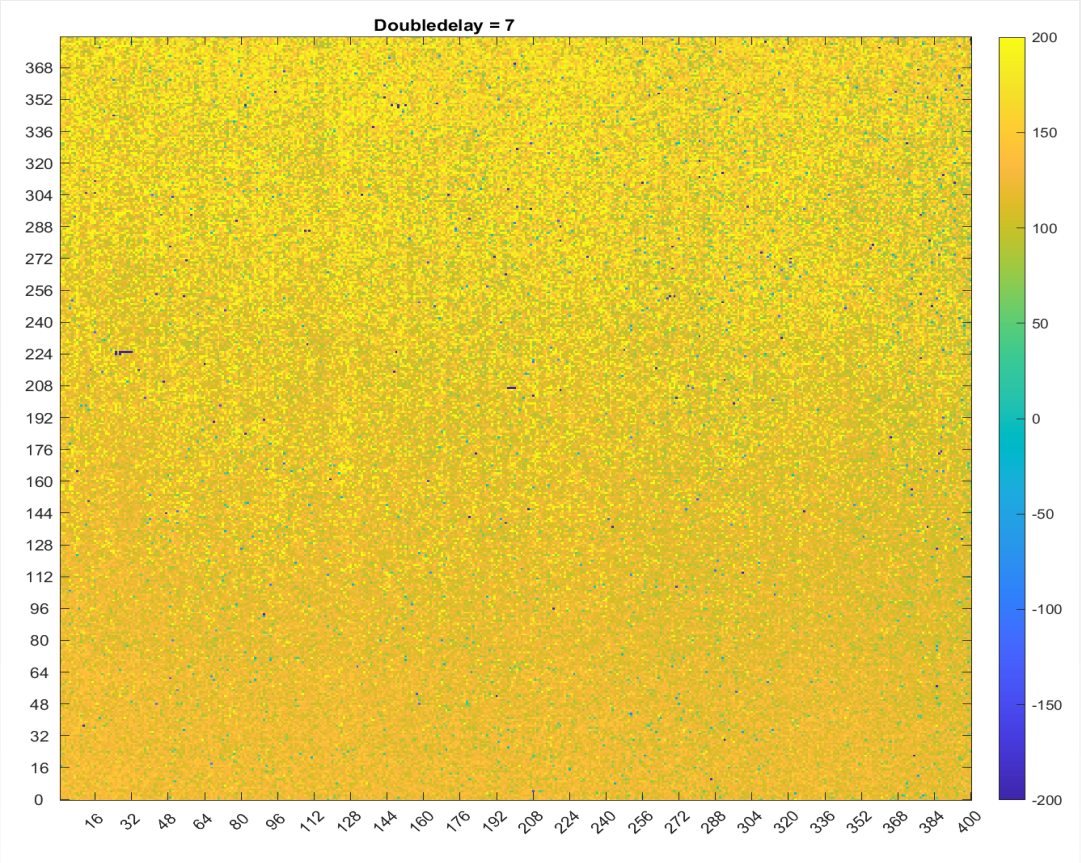
Results: Mean of the threshold vs. double delay

- Tuned with Vcal_Med = 230
- Blue points: Baseline threshold with **#Inj1 set to 0e**
  - Uniform threshold at ~ 2160e
- Red & yellow points: First injection is 4ke and 8ke respectively
- The maximum threshold value increases with larger injections:
  - ~ 2290e (4k), 2340e (8k), 2410 (15k), 2450 (30k)
- This value moves to larger BX for larger injections:
  - ~ 7 BX (4k), 8-9 BX (8k), 10 BX (15k), 12 BX (30k)
- Threshold approaches baseline at ~ 23 BX for both injection scans
- Some small fluctuations



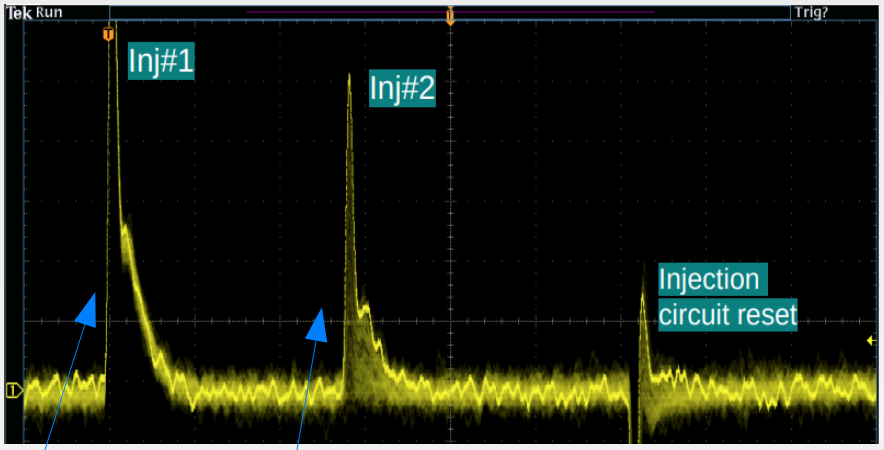
Threshold difference on pixel map

- Tuned with Vcal_Med = 230
- Pixel threshold difference between the 4000e injection scan and the baseline scan
- Double delay = 7 BX
- Colour axis set to +/- 200e
- Think pattern comes from the Vcal_med to gnd tuning

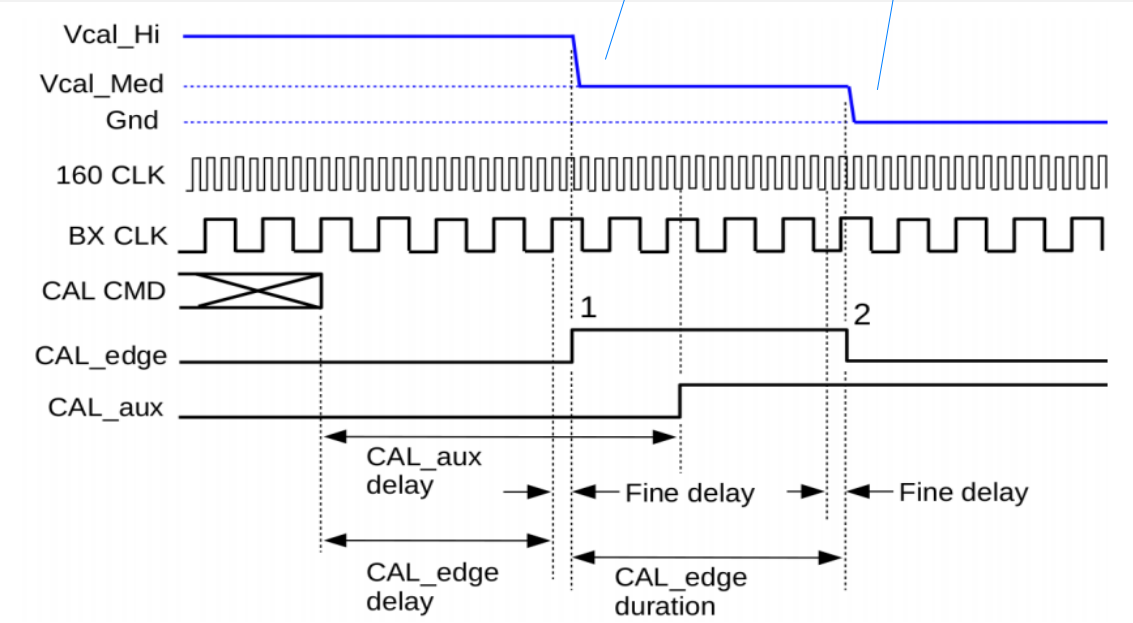


Method 1: Single Cal command

- A double injection can be produced by sending a **single cal command** or by sending **two cal commands** to the chip
- **Single cal command** method shown in figure:
  - Inject charge from **Vcal_Hi to Vcal_Med** and then from **Vcal_Med to Vcal_gnd**

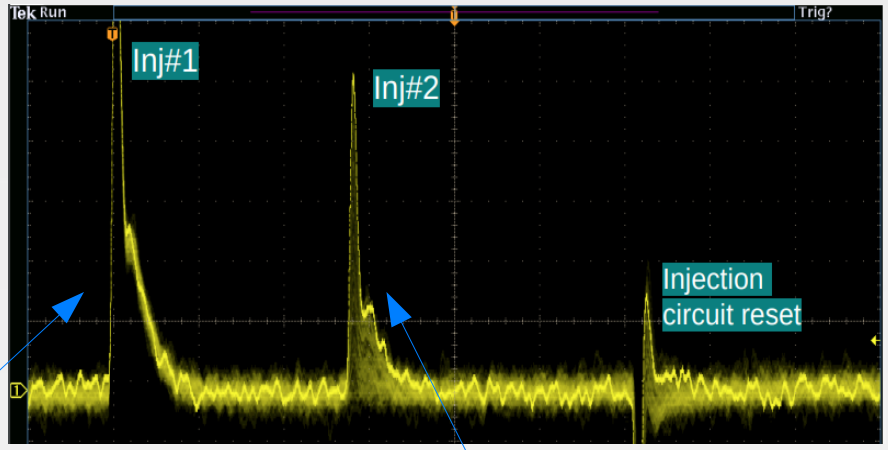


Two injections with one cal command

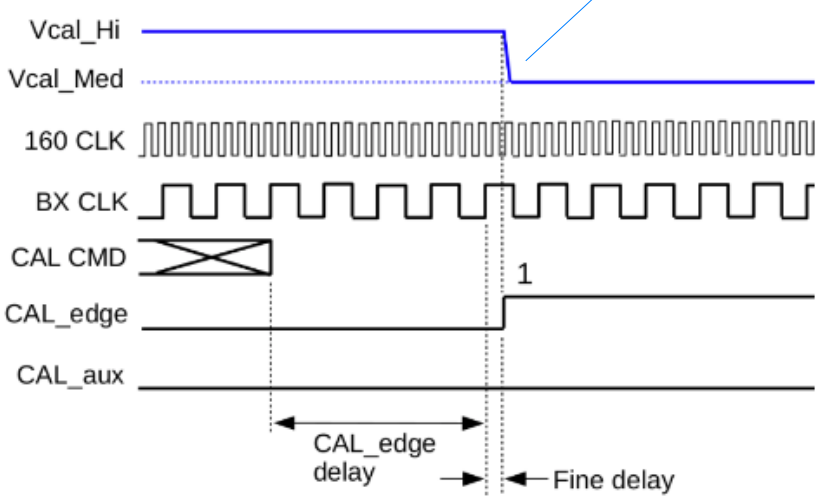


Method 2: Two Cal commands

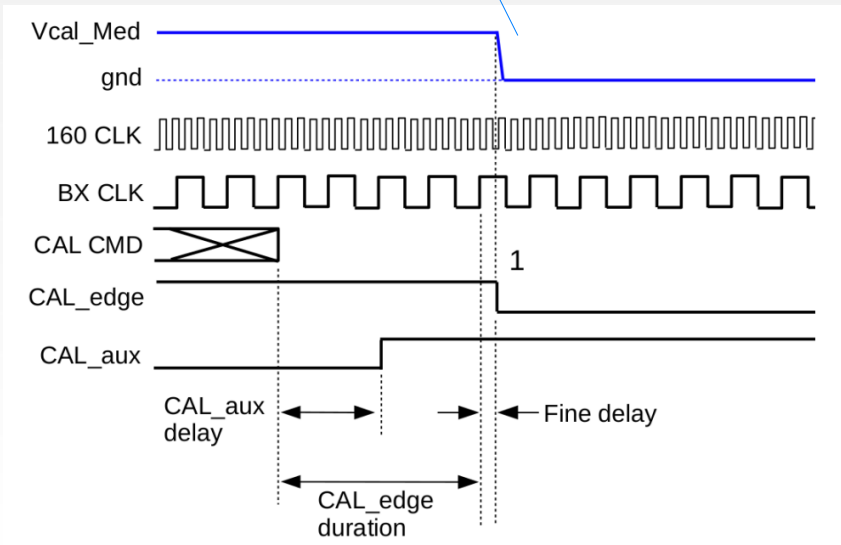
- A double injection can be produced by sending a **single cal command** or by sending **two cal commands** to the chip
- **Two cal commands** as shown in figures:
  - First cal command: Inject charge from **Vcal_Hi to Vcal_Med**
  - Second cal command: Inject charge from **Vcal_Med to Vcal_gnd**



First injection with first cal command

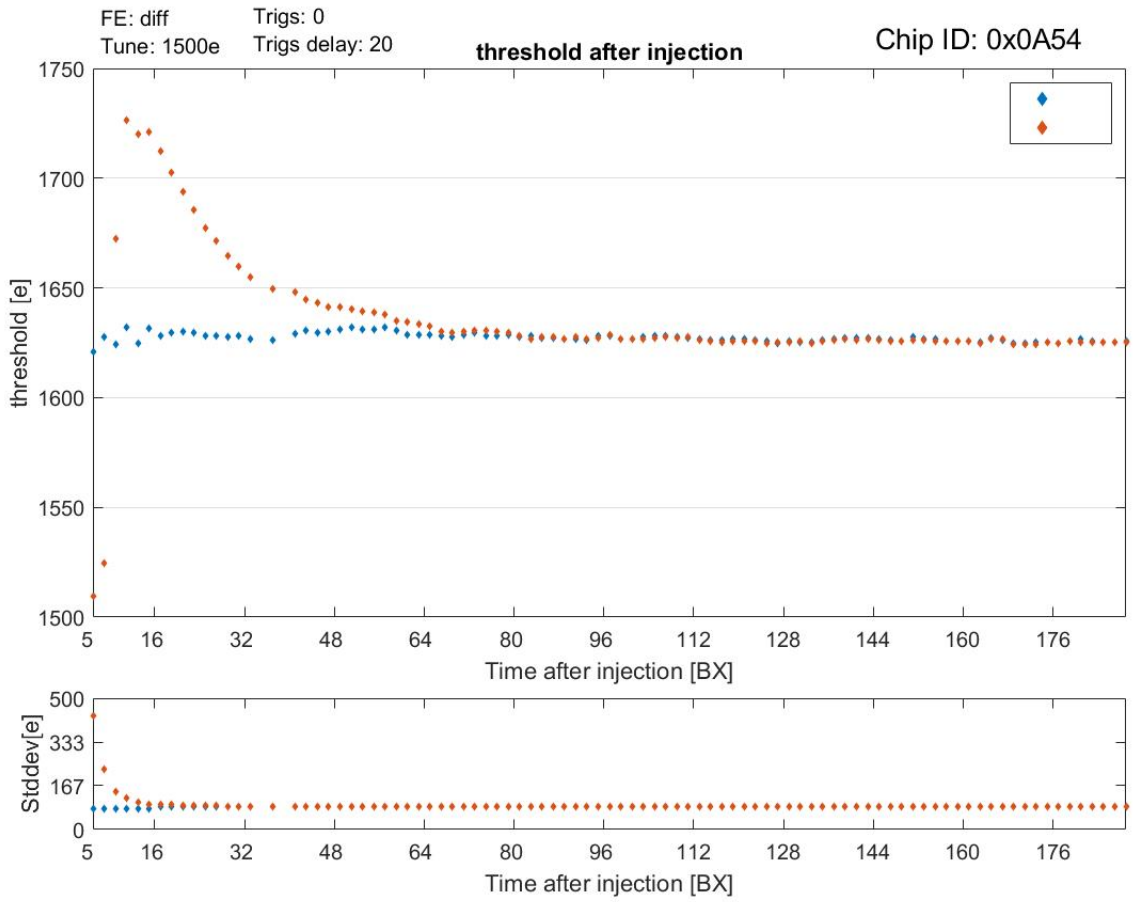


Second injection with second cal command



RD53A: Threshold mean vs. Double delay (Differential FE)

- Diff FE: Tuned to 1500e
- Blue points: **Baseline** (Only have the second charge of varying magnitude)
- Red points: I**nject 2000e** and then inject a second charge of varying magnitude
- X-axis shows the time between the two injections (double delay)
- When the double delay is small - > the mean of threshold increases when having a first injection of 2000e (Red points)
- Most likely caused by the disturbance of the first analog injection or the readout



Double injection on RD53A

- Good news as in the RD53A chip had a bug in the cal command
- The cal edge would go low (if high) right after receiving a CAL CMD.
- Had to change the cal cmd procedure in order to make this work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