

# Ring Oscillator QC Measurement & Analysis

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On behalf of the Module QC Development team

LBNL instrumentation meeting 05/19/2023



**BERKELEY LAB**

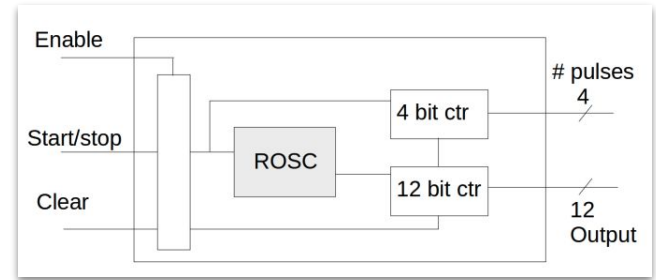


UNIVERSITY OF  
**OREGON**

# Ring oscillators

What are they?

- Test circuits that measure the speed of logic cells.
- They characterise the radiation damage to different gates.
- The oscillation frequency decreases with increasing radiation damage.

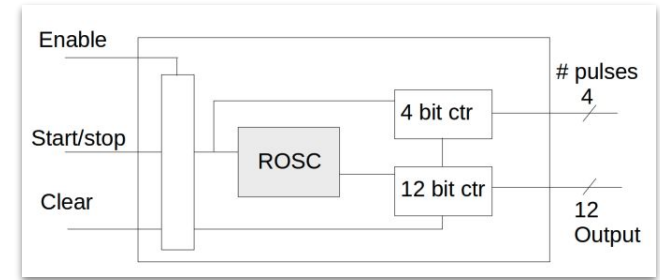


[RD53B manual Figure 75](#)

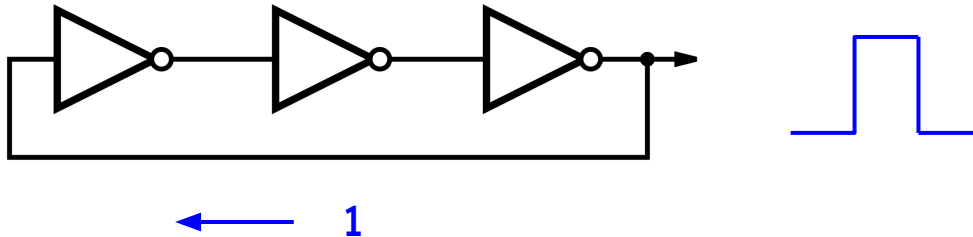
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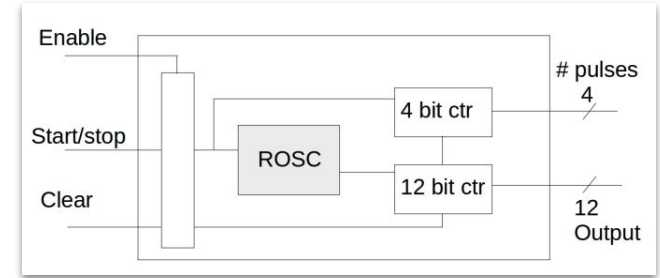
[RD53B manual Figure 75](#)



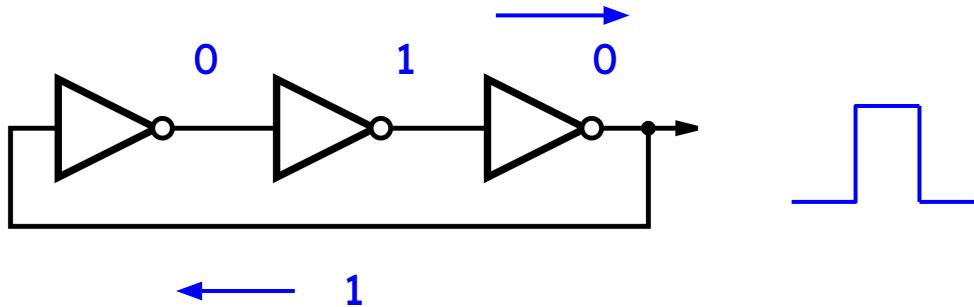
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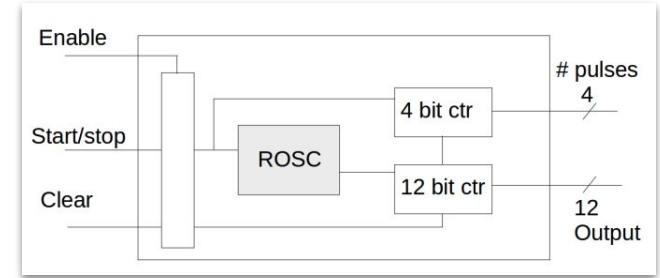
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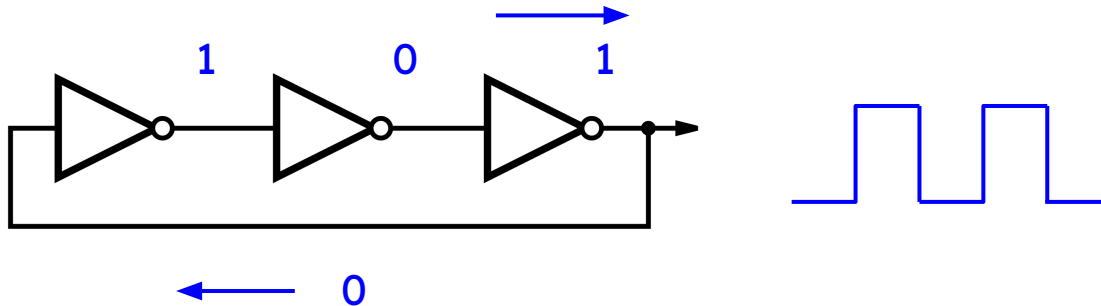
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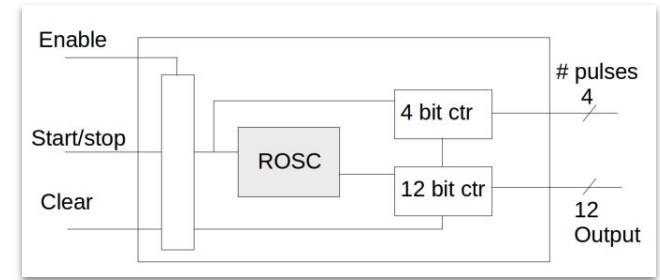
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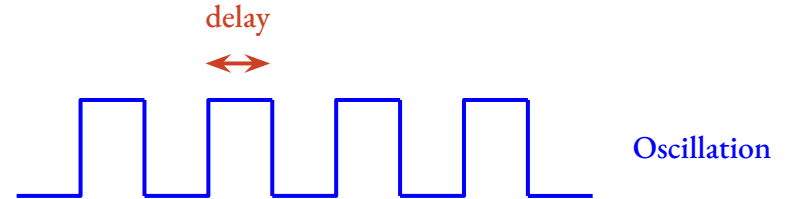
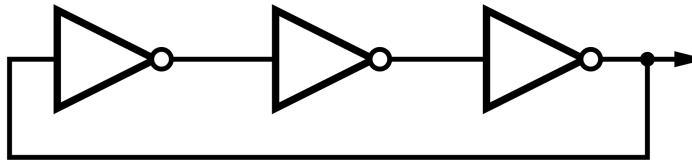
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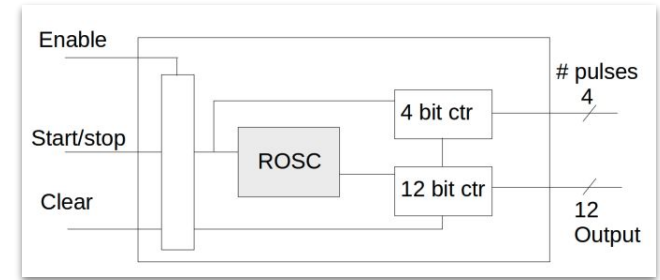
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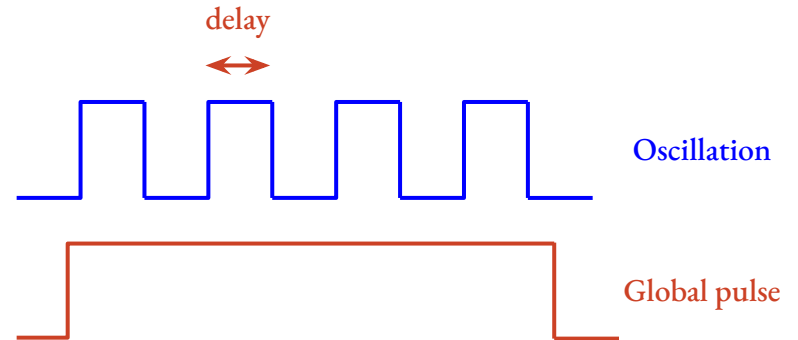
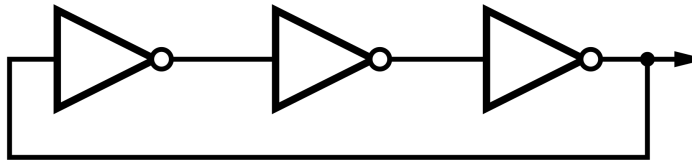
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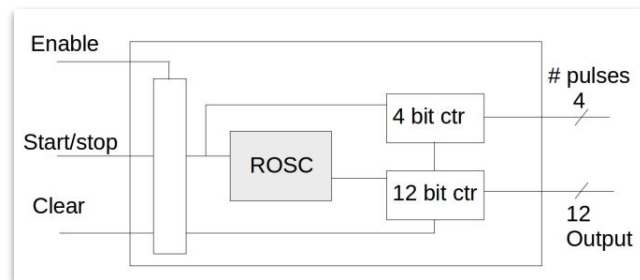
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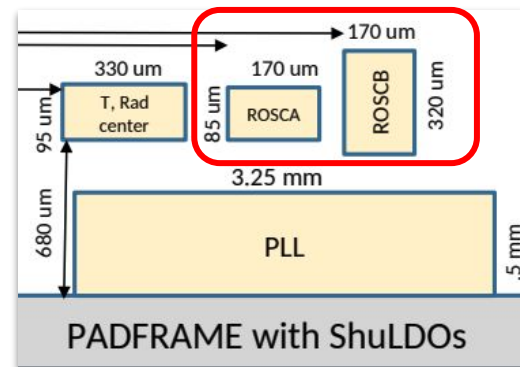
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Where are they?

- Located in two banks in the chip bottom
  - Bank A has 8 ROSCs (same ones as RD53A)
  - Bank B has 34 ROSCs



[RD53B manual Figure 75](#)



[RD53B manual Figure 4](#)



# Ring oscillators

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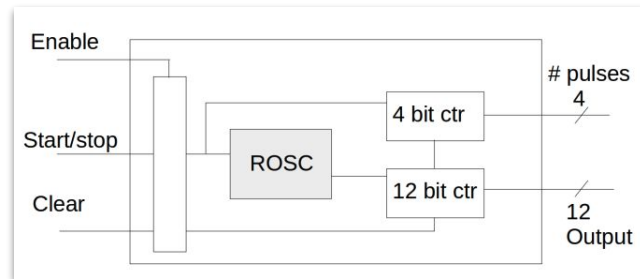
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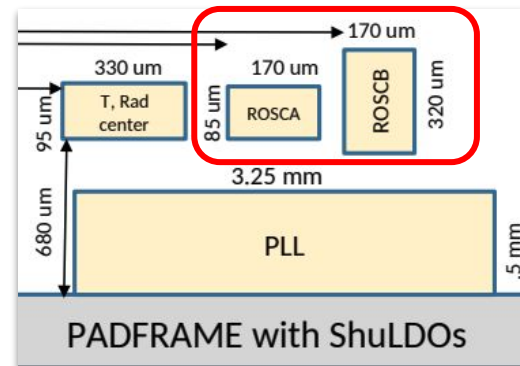
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  - Bank B has 34 ROSCs

Why do we measure them in QC?

- It is important to make sure the chip has working ROSCs.
- We can collect raw measurements before radiation.



[RD53B manual Figure 75](#)



[RD53B manual Figure 4](#)

# Measurement in QC

What do we measure?

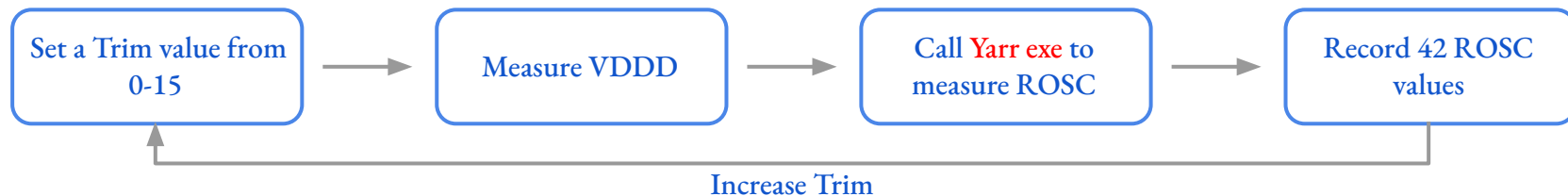
- The oscillation frequency in MHz as a function of VDDD under different Trim values (also temperature).
- We expect a linear relation where the slopes and offsets are determined for each ring oscillator.

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How do we measure?

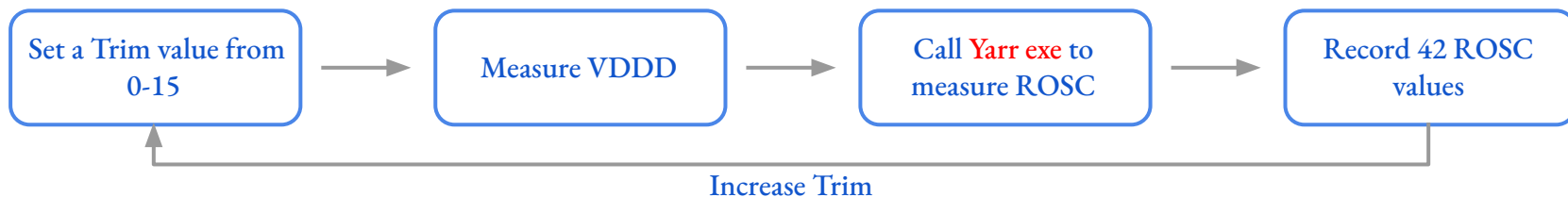


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- The oscillation frequency in MHz as a function of VDDD under different Trim values (also temperature).
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How do we measure?



The users needs to

1. Update YARR to the latest version.
2. Add `rd53bReadRingosc` exe to QC config.

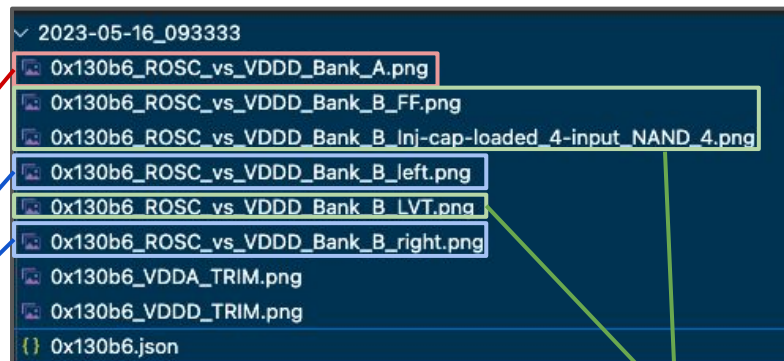
```
"yarr": {
  "run_dir": "../Yarr",
  "controller": "configs/controller/specCfg-rd53b-16x1.json",
  "scanConsole_exe": "./bin/scanConsole",
  "write_register_exe": "./bin/write-register",
  "read_adc_exe": "./bin/read-adc",
  "switchLPM_exe": "./bin/switchLPM",
  "lpm_digitalscan": "configs/scans/rd53b/lpm_digitalscan.json",
  "read_ringosc_exe": "./bin/rd53bReadRingosc"
```

# Analysis in QC

## ROSC vs VDDD output

- 42 SLOPEs and 42 OFFSETs
- 6 plots, grouped by ROSC types and locations

ROSC Nbr.	Type	Len.	ROSC Nbr.	Type	Len.
0	Strgth. 0 inv. clk. drvvr.	55	4	Strgth. 0 4-input NAND	19
1	Strgth. 4 inv. clk. drvvr.	51	5	Strgth. 4 4-input NAND	19
2	Strgth. 0 inverter	55	6	Strgth. 0 4-input NOR	19
3	Strgth. 4 inverter	51	7	Strgth. 4 4-input NOR	19

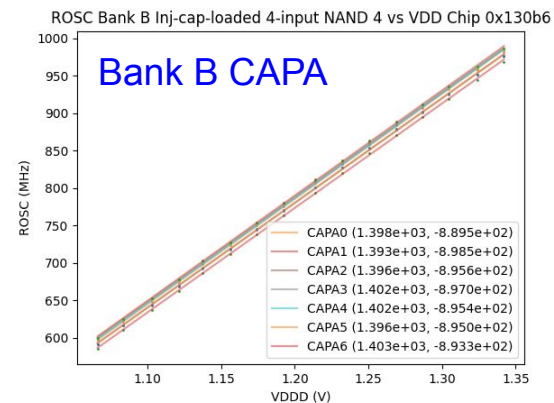
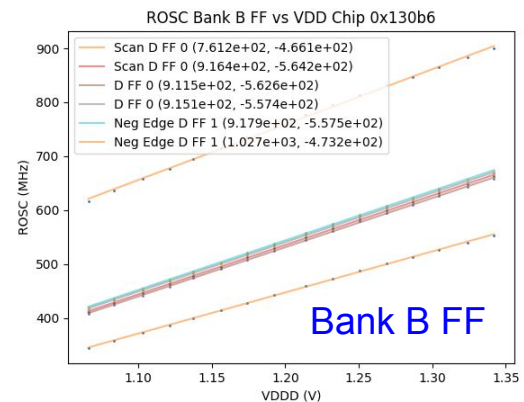
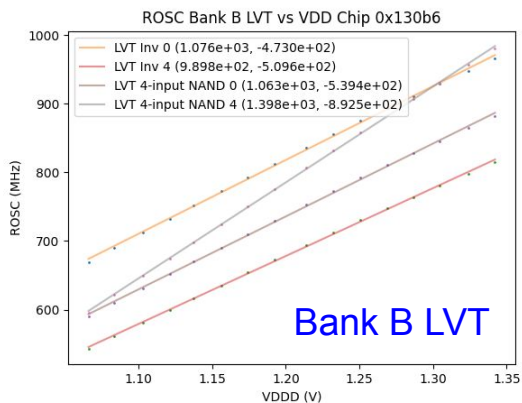
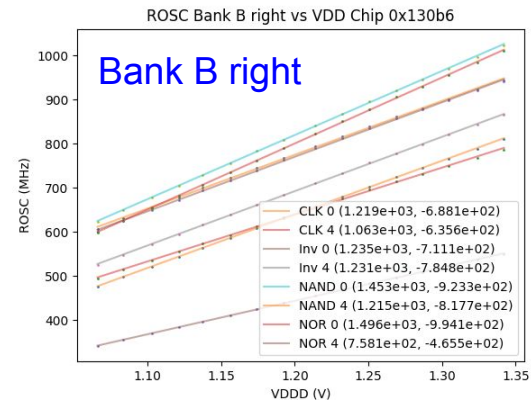
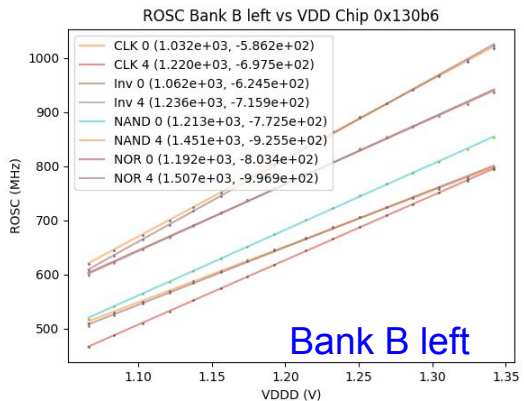
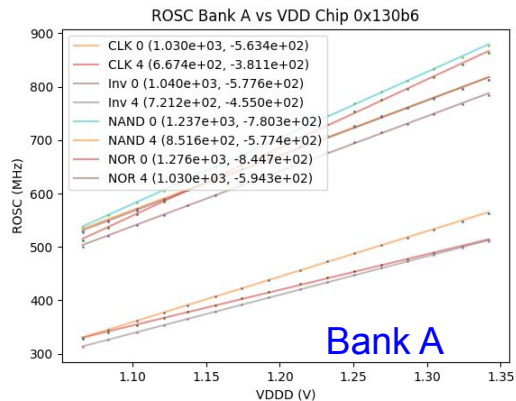


ROSC Nbrs.	Type	Eff. Len.	Group
0 & 1	Strgth. 0 inv. clk. driver	38.2	B-left, B-right
2 & 3	Strgth. 4 inv. clk. driver	44.5	B-left, B-right
4 & 5	Strgth. 0 inverter	38.1	B-left, B-right
6 & 7	Strgth. 4 inverter	44.3	B-left, B-right
8 & 9	Strgth. 0 4-input NAND	12.6	B-left, B-right
10 & 11	Strgth. 4 4-input NAND	16	B-left, B-right
12 & 13	Strgth. 0 4-input NOR	14.5	B-left, B-right
14 & 15	Strgth. 4 4-input NOR	14.5	B-left, B-right

16 & 17	Strgth. 0 scan D-flip-flop	6.1	FF
18 & 19	Strgth. 1 D-flip-flop	6.2	FF
20 & 21	Strgth. 1 Neg. edge D-flip-flop	5	FF
22	Strgth. 0 LVT inverter	40.6	LVT
23	Strgth. 4 LVT inverter	56	LVT
24	Strgth. 0 LVT 4-input NAND	16.5	LVT
25	Strgth. 4 LVT 4-input NAND	22.8	LVT
26-33	Strgth. 4 inj-cap-loaded 4-input NAND	16.8	CAPA

[RD53B manual Table 41-42](#)

# Analysis in QC

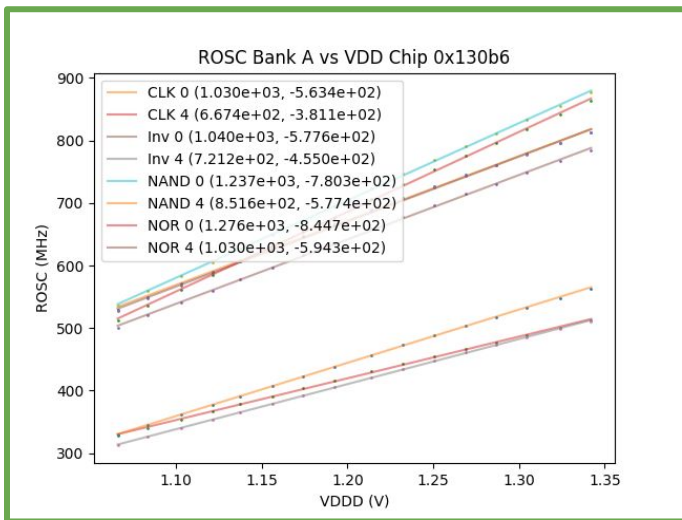


# QC PASS/FAIL

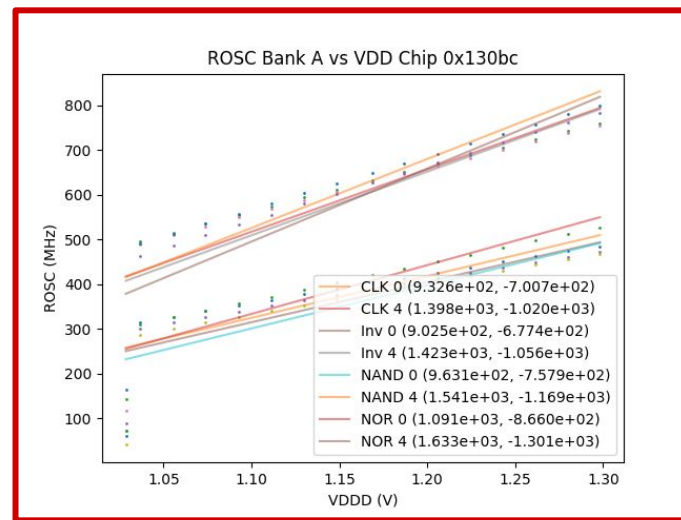
## Current QC cuts

- AR\_ROSC\_SLOPE
  - AR\_ROSC\_OFFSET
  - AR\_ROSC\_MAX\_RESIDUAL (maximum difference between data and prediction from the linear fit)
- ← These cuts needs to be studied more!

Pass



Fail



## Take away

- Ring Oscillator measurement is a new feature in Module QC V2.
- It is part of the ANALOG\_READBACK test.
- Update module-qc-tools and YARR in order to perform this test!

```
"yarr": {  
  "run_dir": "../Yarr",  
  "controller": "configs/controller/specCfg-rd53b-16x1.json",  
  "scanConsole_exe": "./bin/scanConsole",  
  "write_register_exe": "./bin/write-register",  
  "read_adc_exe": "./bin/read-adc",  
  "switchLPM_exe": "./bin/switchLPM",  
  "lpm_digitalscan": "configs/scans/rd53b/lpm_digitalscan.json",  
  "read_ringosc_exe": "./bin/rd53bReadRingosc"
```

[example\\_merged\\_vmux.json](#)



**Back up**

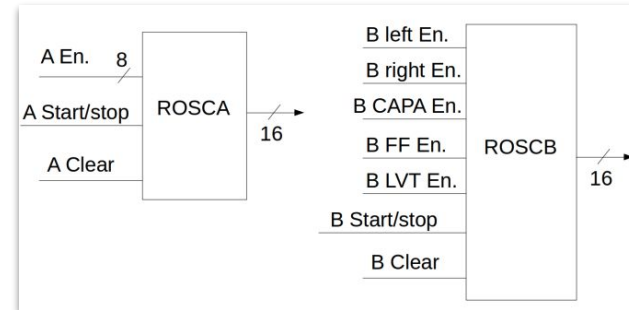
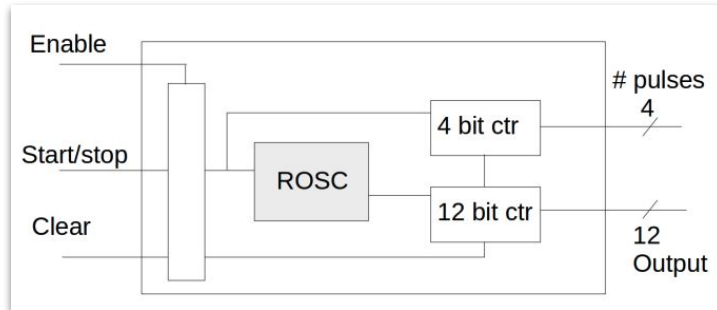
## Back up

Each ring oscillator is a chain made of different logic cells.

The number of cells in each ring was chosen to have approximately the same frequency.

Each ring oscillator drives a 12-bit counter, which is enabled for a given time.

During this time, the ring oscillator output oscillates between 0 and 1 with a particular frequency, given by the delay of the gate used.



[RD53B manual](#)