DLL-Based Thermal Sensor

2020.11.27

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Outline

- Introduction
- DLL-based thermal sensor architecture
  - Top level
  - Tunable Delay Line
  - Calibration
- Experimental results

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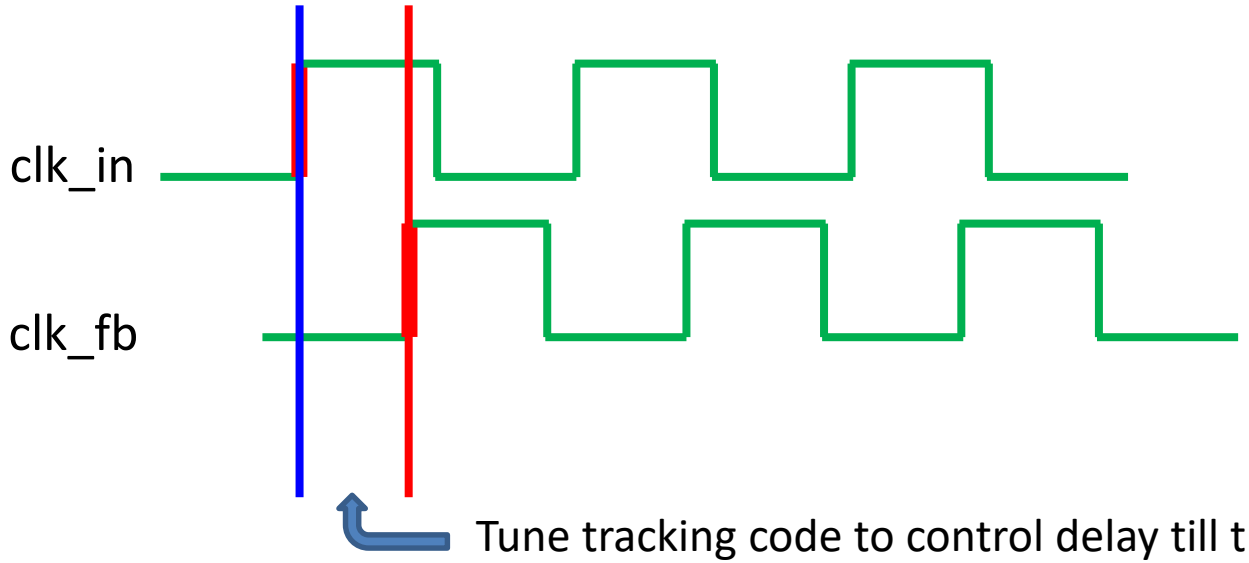
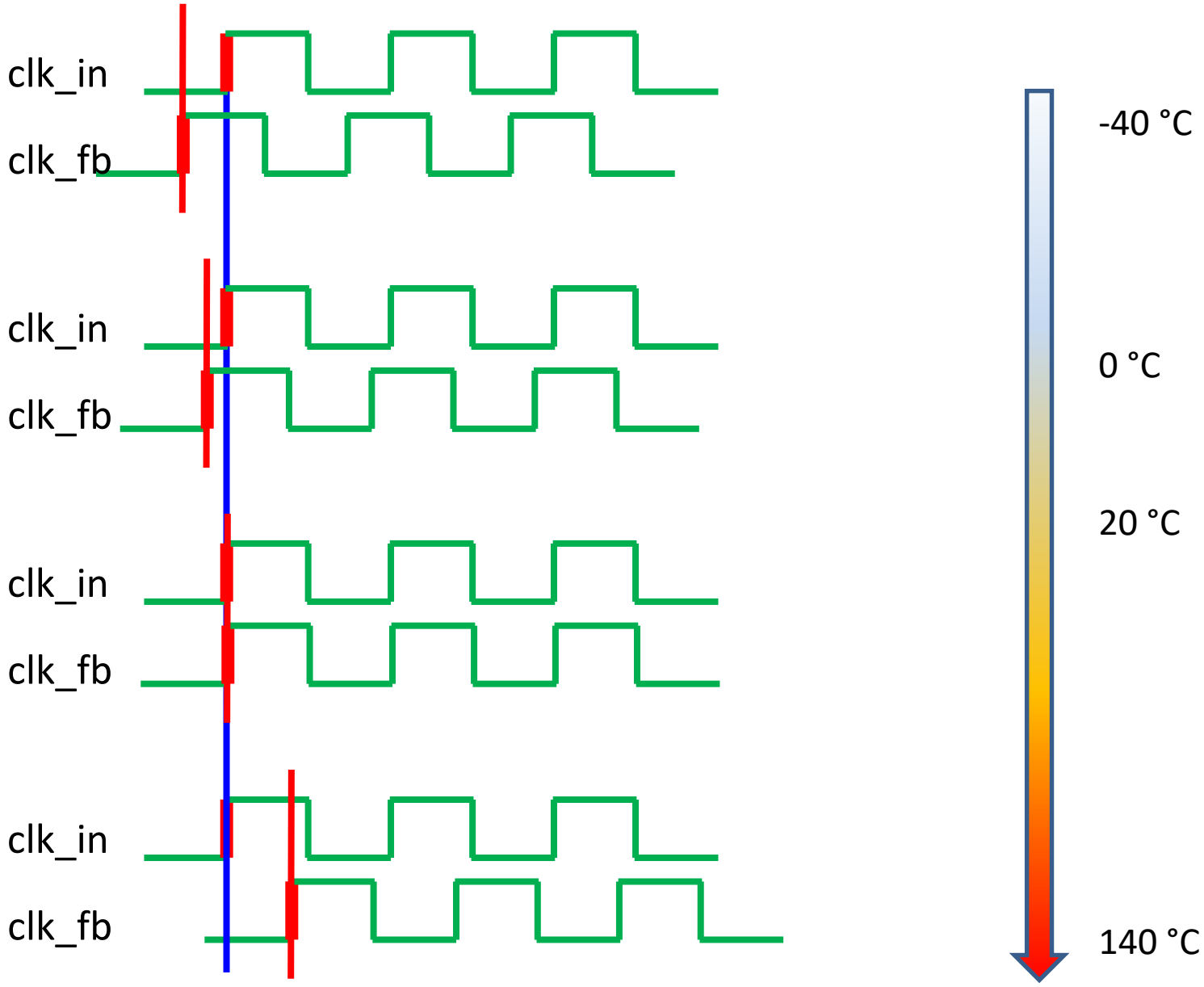
Delay Locked Loop (DLL)

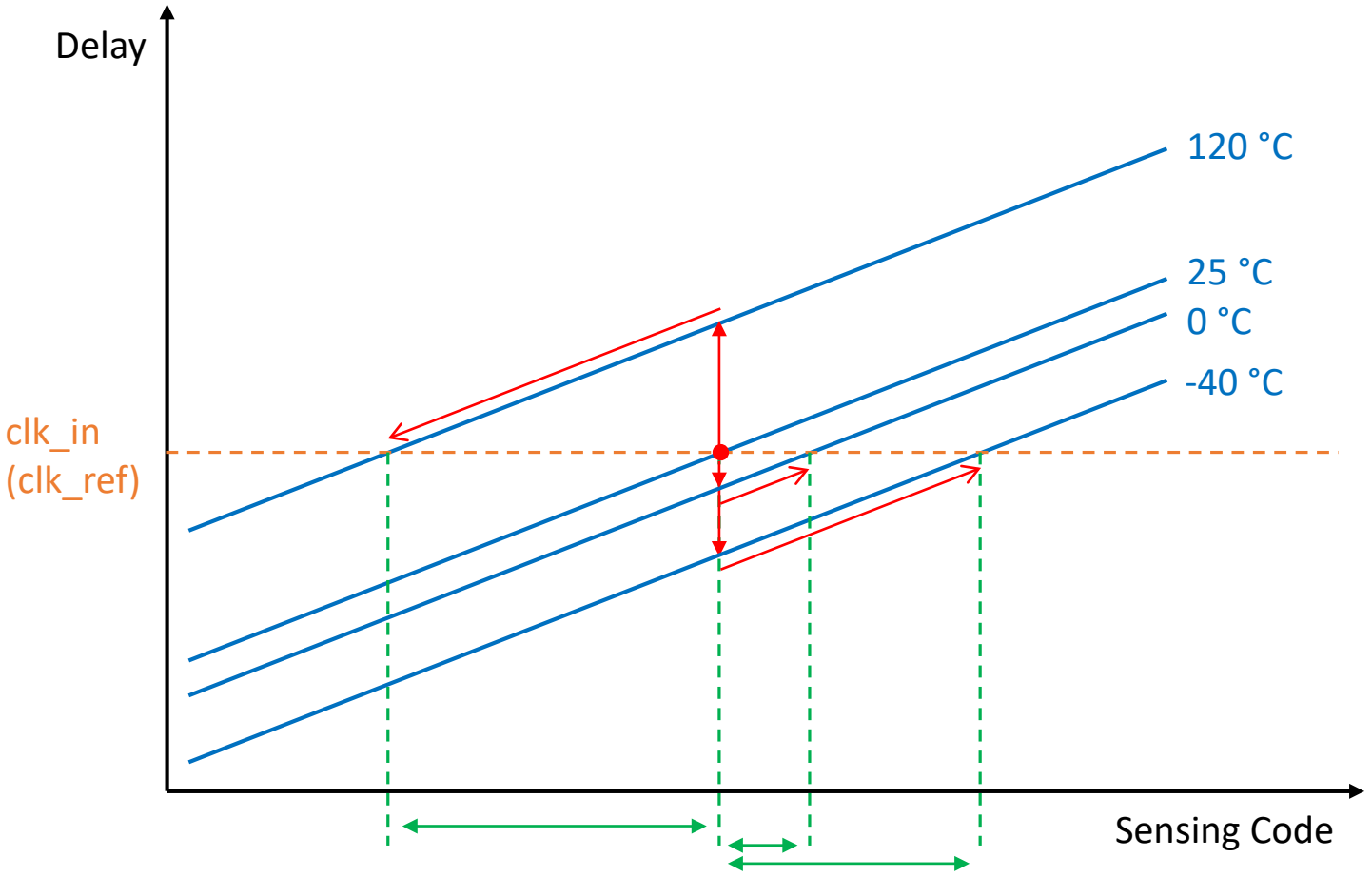


Tune tracking code to control delay till they align (locked)

Delay Variation Under Different Temperatures



Basic Idea



Δ Sensing Code → Estimate temperature variation

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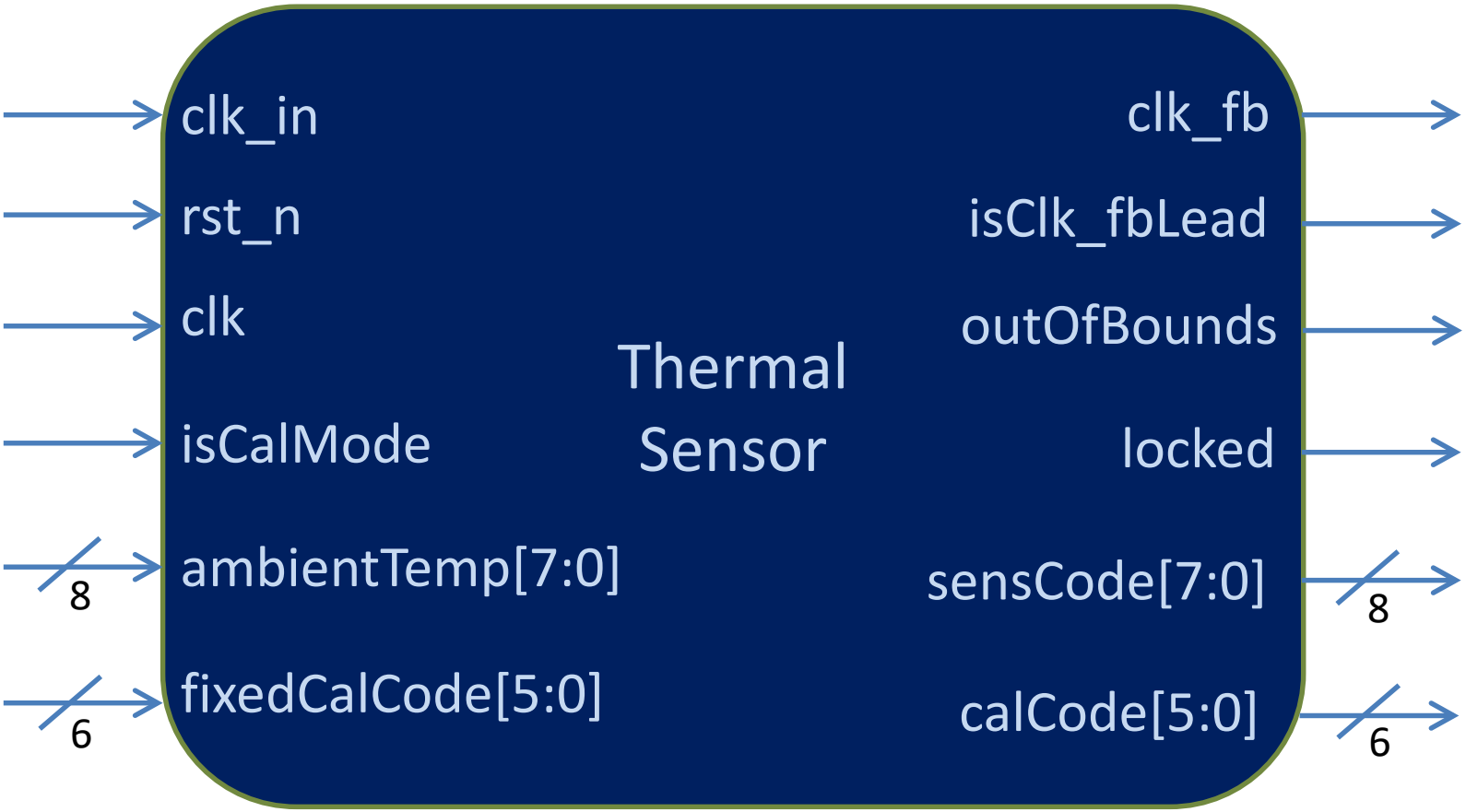
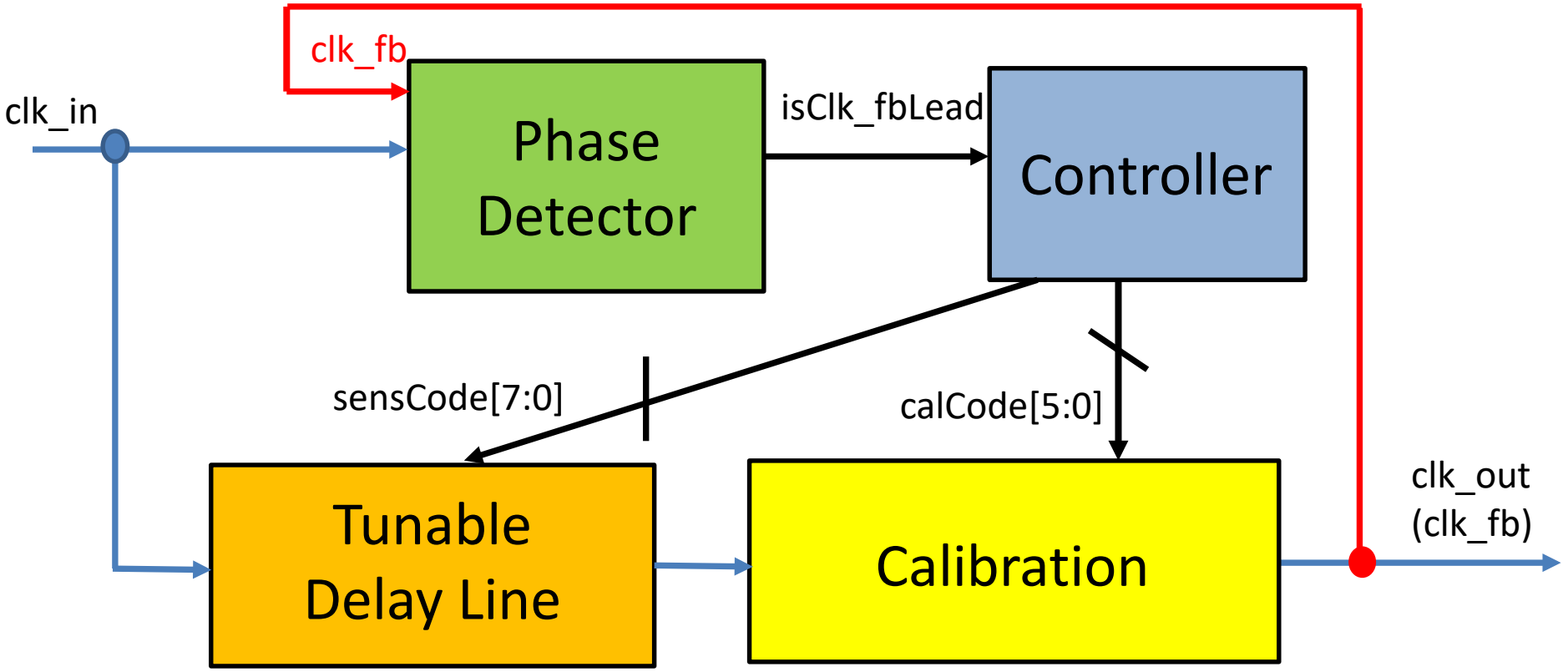
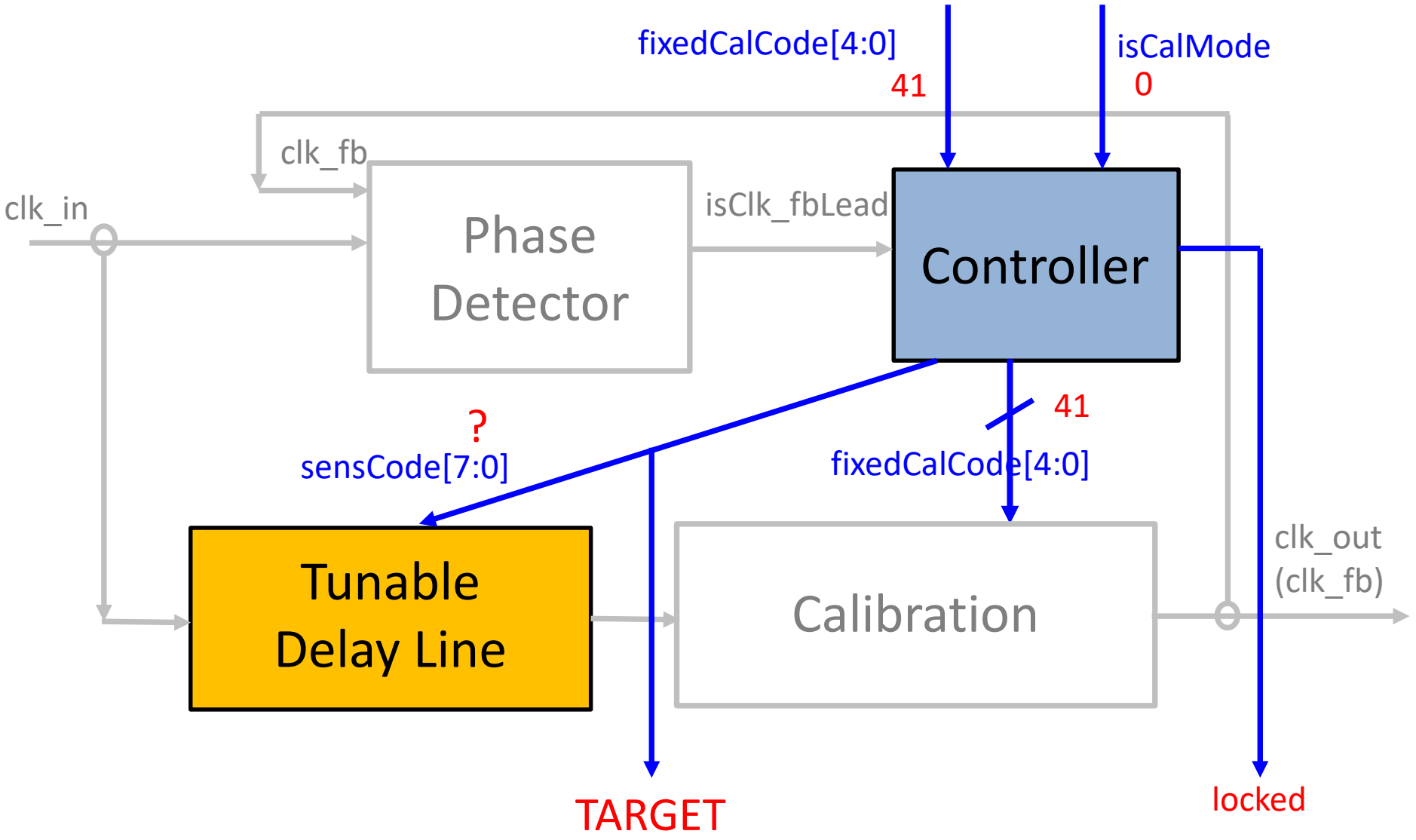
Top Level


clk_in
rst_n
clk
isCalMode
ambientTemp[7:0]
8
fixedCalCode[5:0]
6
Thermal Sensor
clk_fb
isClk_fbLead
outOfBounds
locked
sensCode[7:0]
8
calCode[5:0]
6

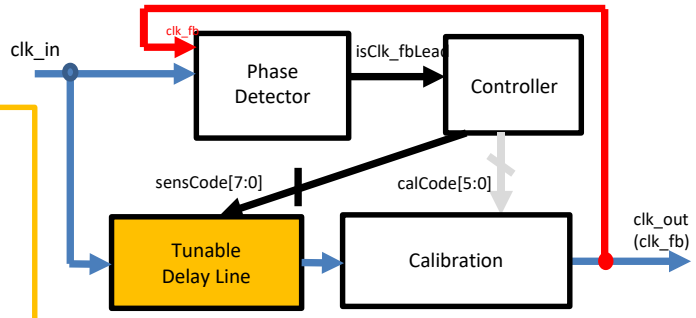
Architecture

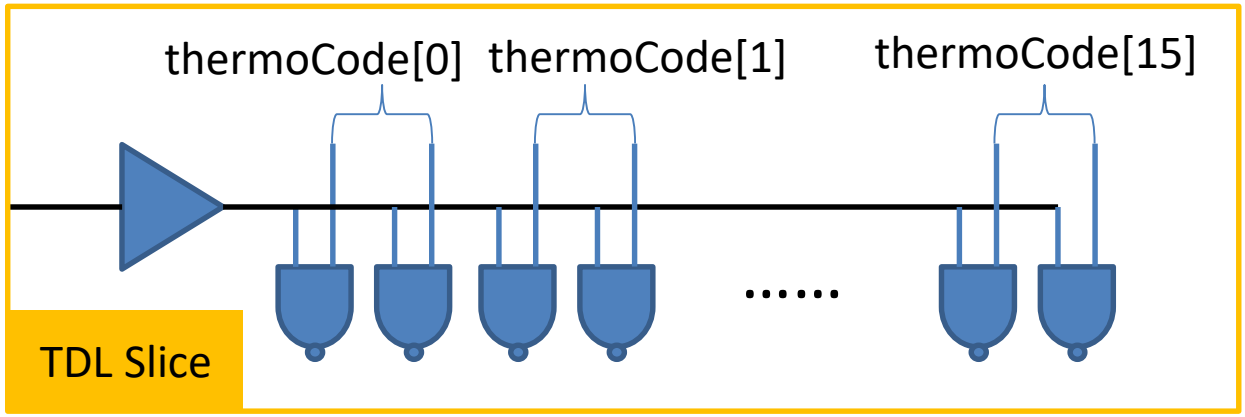


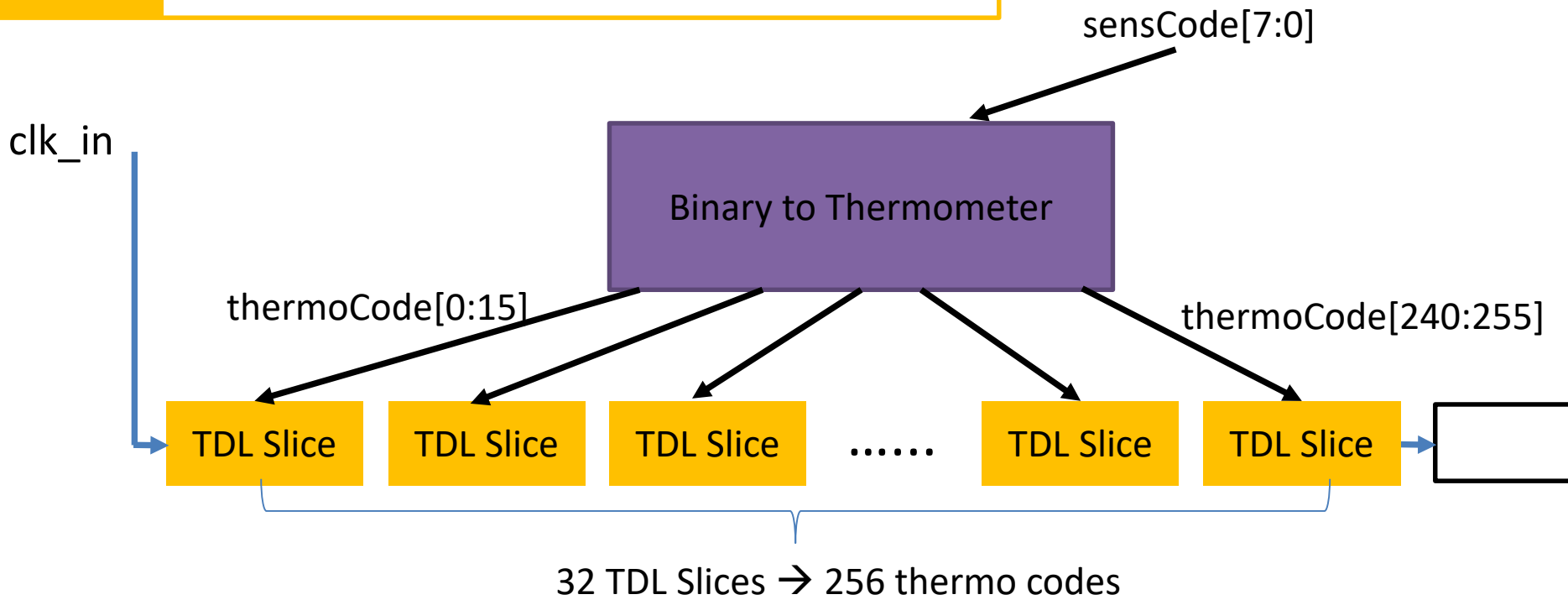
Sensing Mode



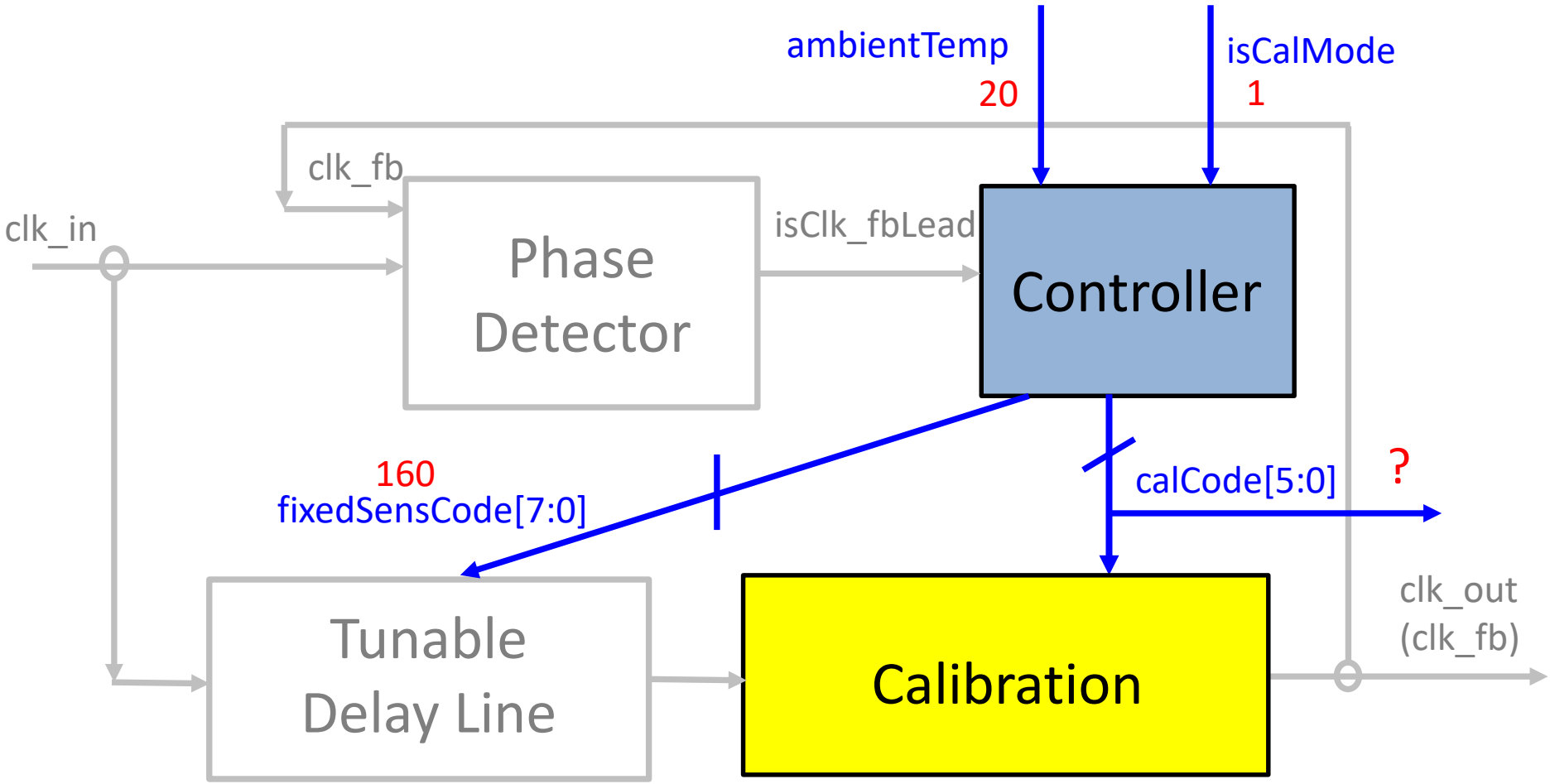
Sensing Mode



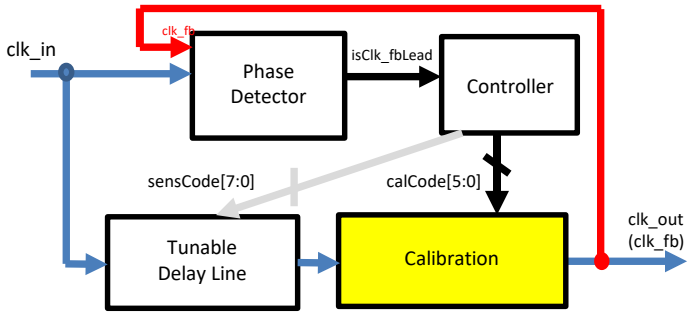




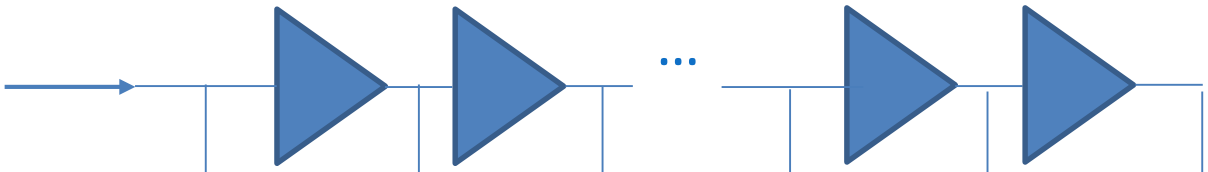
Calibration



Calibration



CLKBUFX1



bufferOut[0] bufferOut[1] ... bufferOut[30] bufferOut[31]

calCode[5:0]

Selection

clk_out

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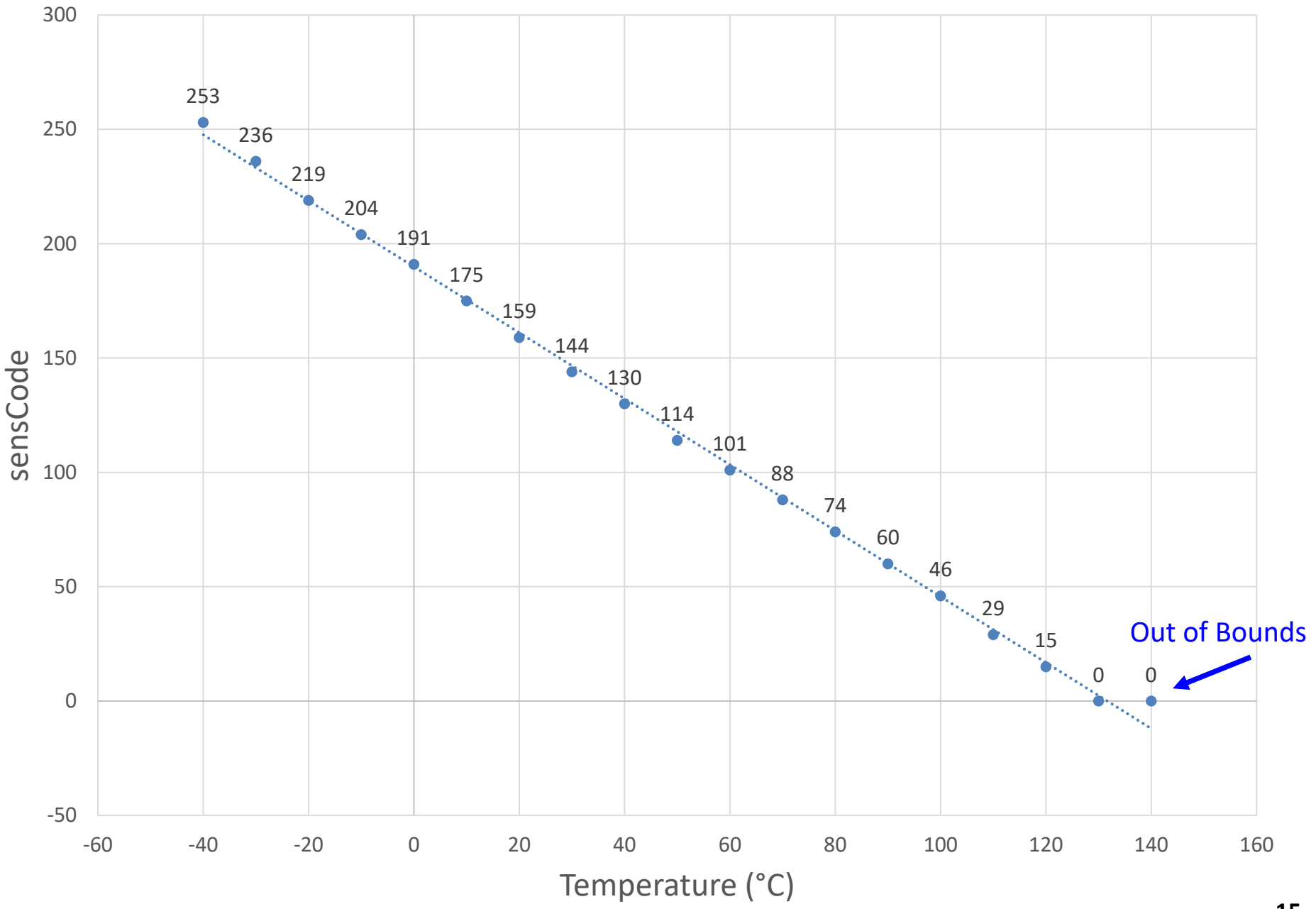
Correlation between locked Sensing Code & Temperature
sensCode
Temperature (°C)
300
250
200
150
100
50
0
-50
-60
-40
-20
0
20
40
60
80
100
120
140
160
253
236
219
204
191
175
159
144
130
114
101
88
74
60
46
29
15
0
0
Out of Bounds

Future Work

- Simulate under other corners
- Possibility of using it as a central indicator which reports exact temperature information (Ex: calibrate other sensors within the whole chip, underclocking in processor units)

Thanks for your listening !

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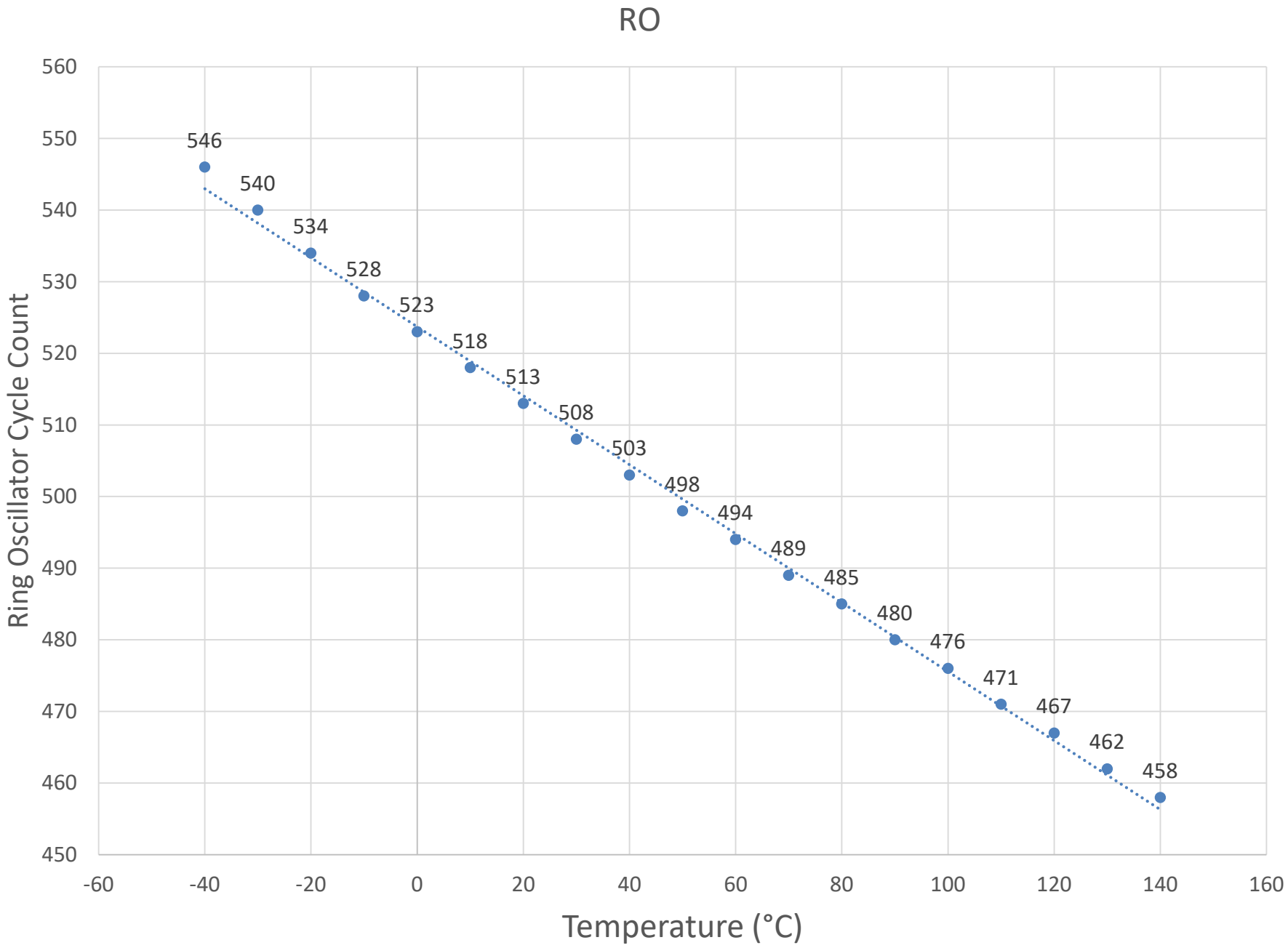
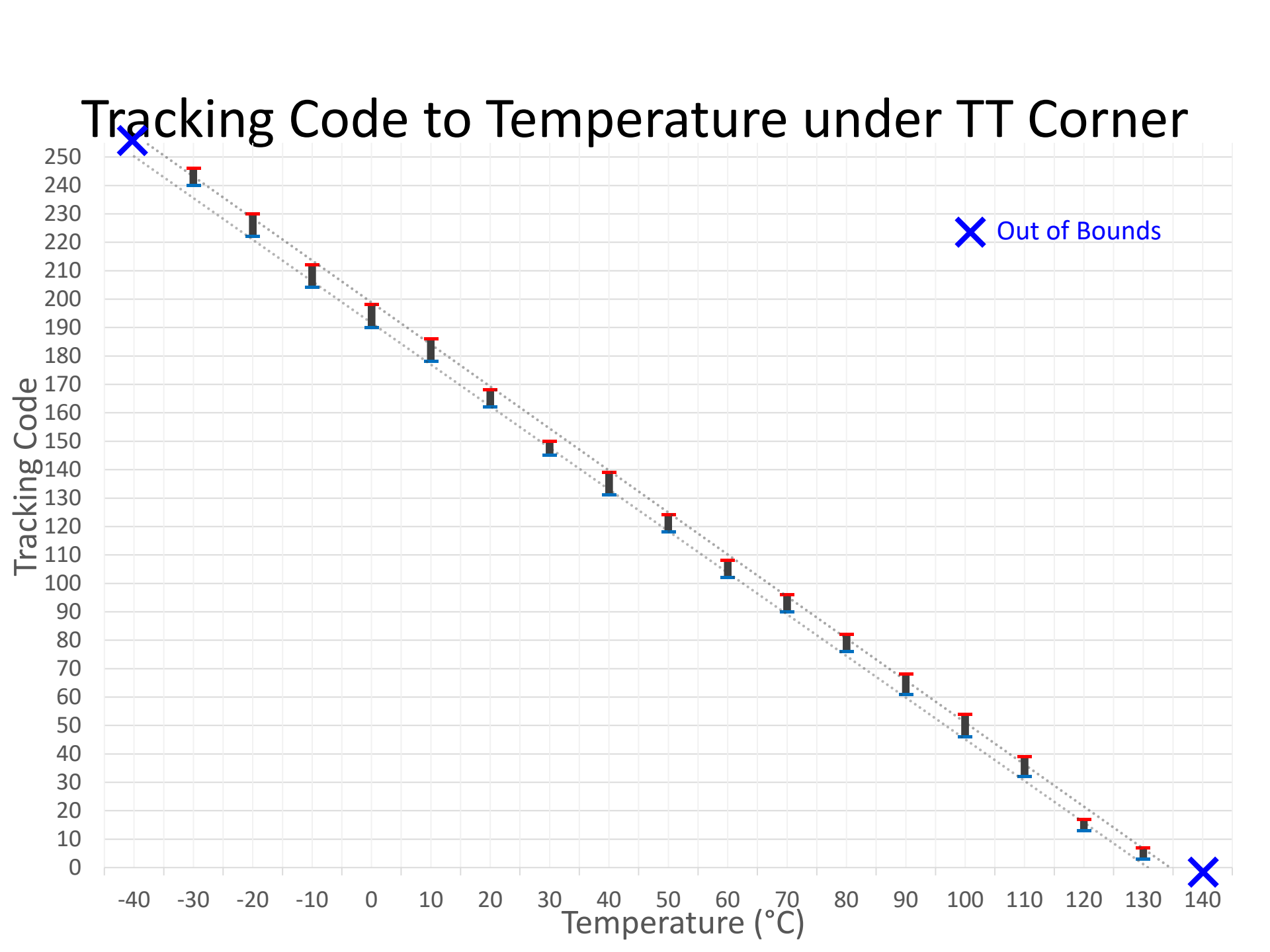
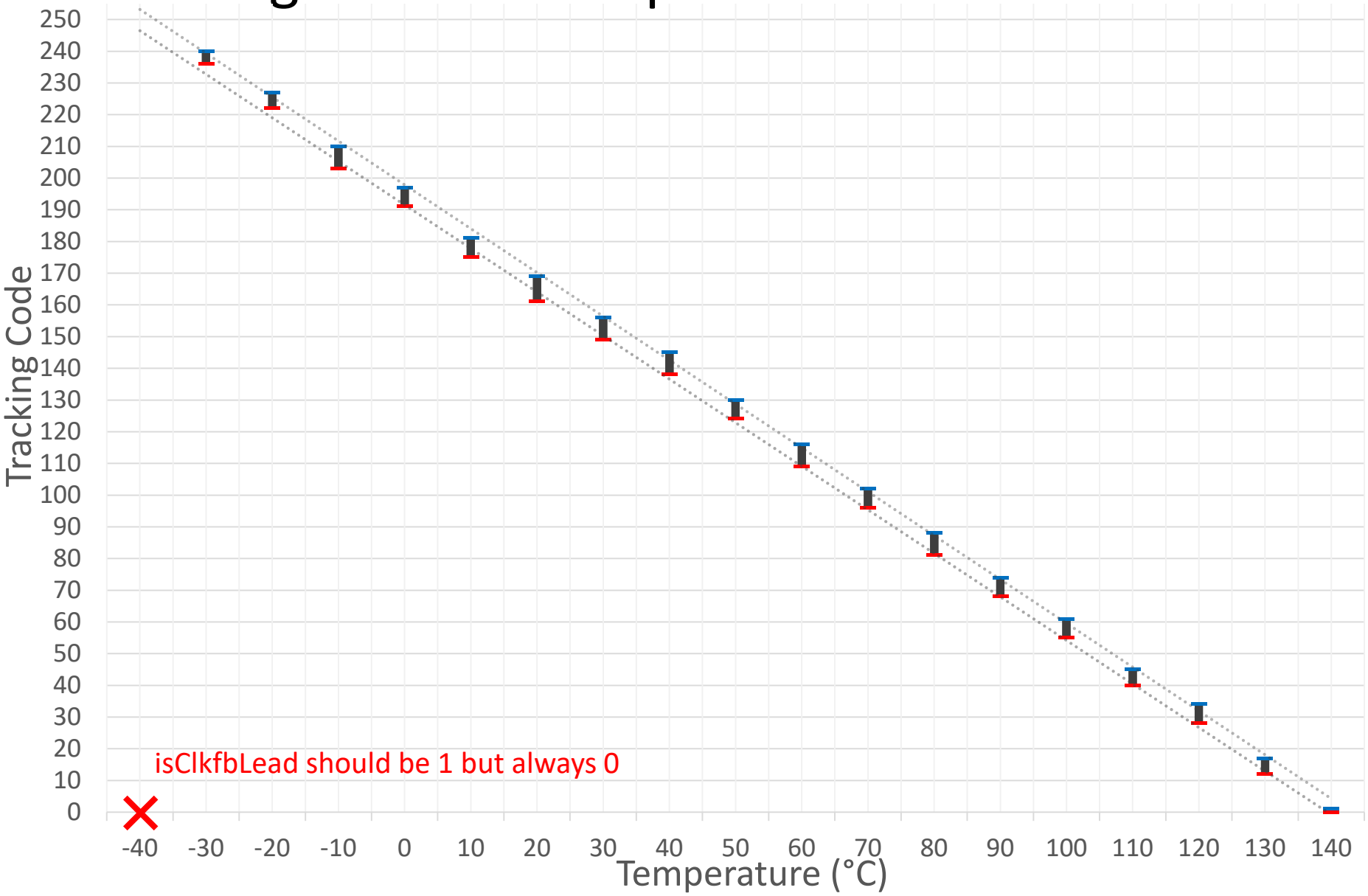
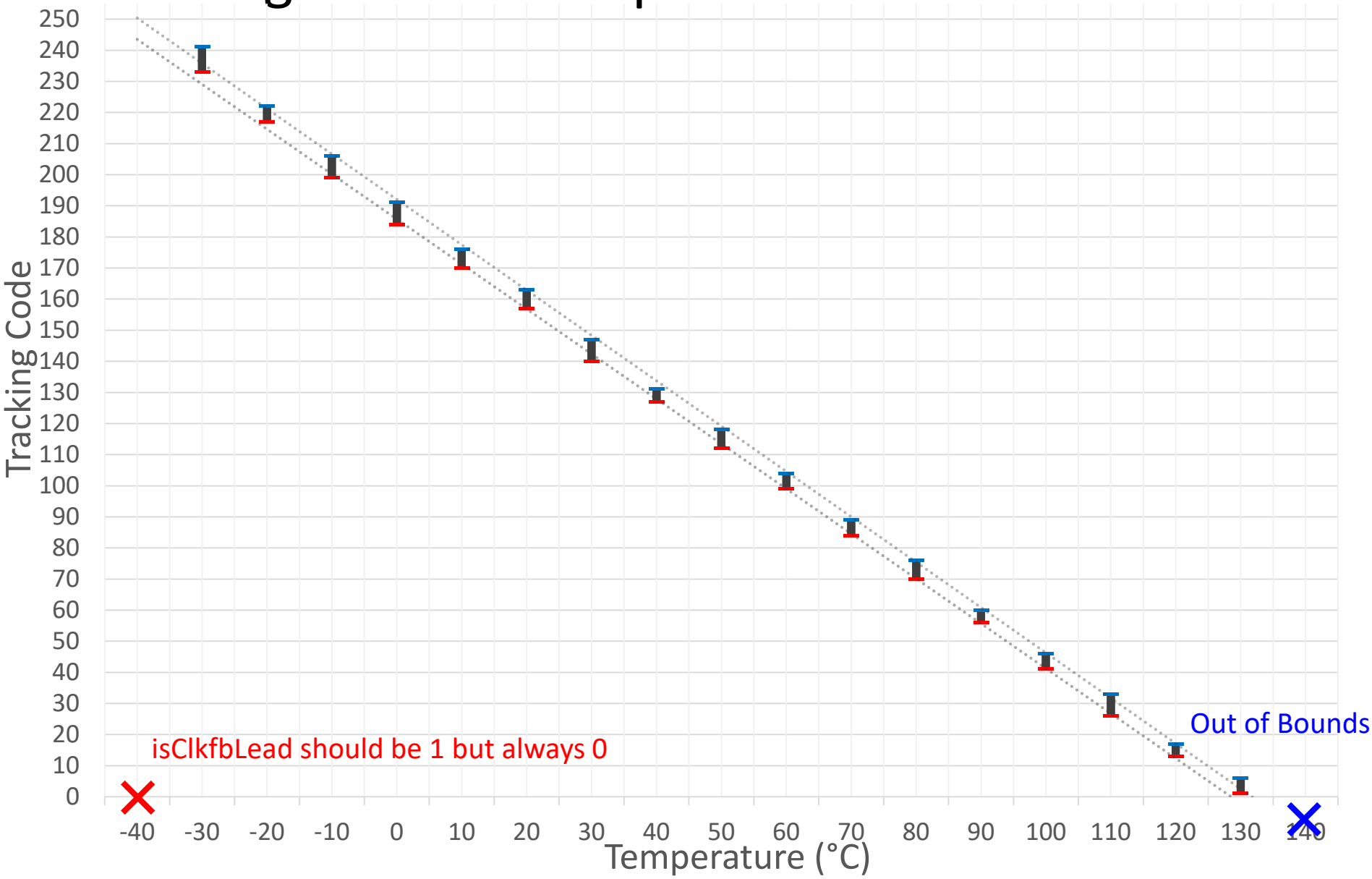

RO
Ring Oscillator Cycle Count
Temperature (°C)
560
550
540
530
520
510
500
490
480
470
460
450
-60
-40
-20
0
20
40
60
80
100
120
140
160
546
540
534
528
523
518
513
508
503
498
494
489
485
480
476
471
467
462
458

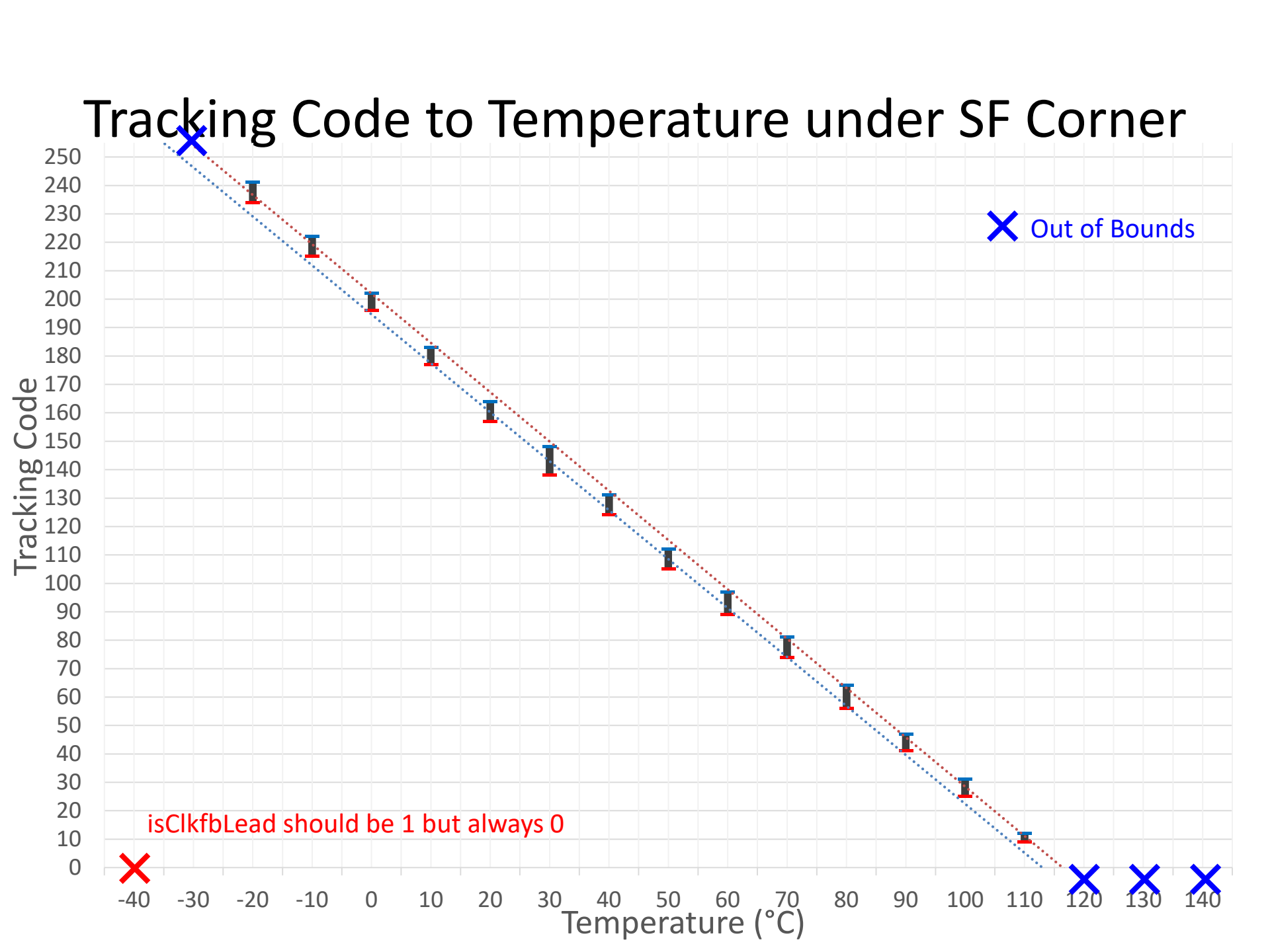

Tracking Code to Temperature under TT Corner
Out of Bounds
Tracking Code
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Temperature (°C)

Tracking Code to Temperature under FS Corner



Tracking Code to Temperature under FF Corner




Tracking Code to Temperature under SF Corner
Tracking Code
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Temperature (°C)
Out of Bounds
isClkfbLead should be 1 but always 0

Tracking Code to Temperature under SS Corner