Toward SSC Modulation Specs and Link Budget

(Spreading the Pain)

Guillaume Fortin, Rick Hernandez & Mathieu Gagnon
PMC-Sierra

Overview

PMC-SIERRA
Enabling connectivity. Empowering people.

- The JTF as a model of CDR performance
- Using the JTF to qualify SSC modulation
- Simulation Methodology
- Frequency Modulation and Jitter
  - Triangular
  - Hershey Kiss
  - Square Wave
- Limitation of the JTF as CDR model
- Residual SSC Jitter Summary
- Theoretical Value of Residual Jitter
- How much SSC jitter is too much jitter?
  - Tentative Link Budget
- Tentative SSC Specifications

The JTF as a model of CDR performance

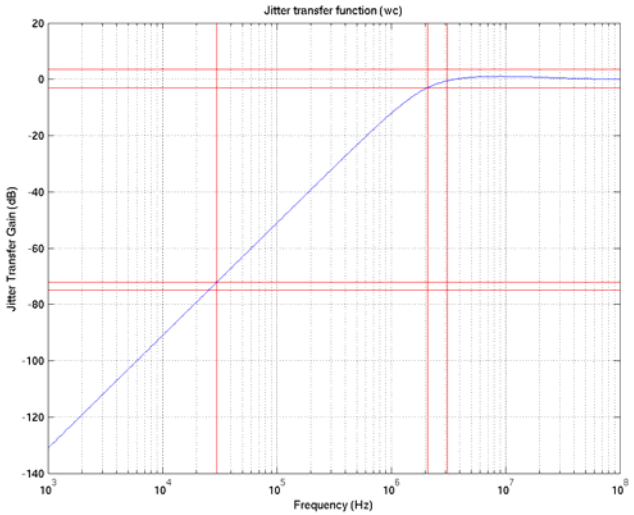
PMC-SIERRA
Enabling connectivity. Empowering people.

- When measuring jitter on the transmitter signal, the main objective should be to verify that this jitter is low enough to guarantee a robust link.
- Applying the jitter transfer function (JTF) on the transmitter jitter removes jitter components.
- The underlying assumption is that the jitter components that are removed do not impact link robustness
  - In other words, *the JTF represents the assumed performance of a CDR in a SAS-2 system*.

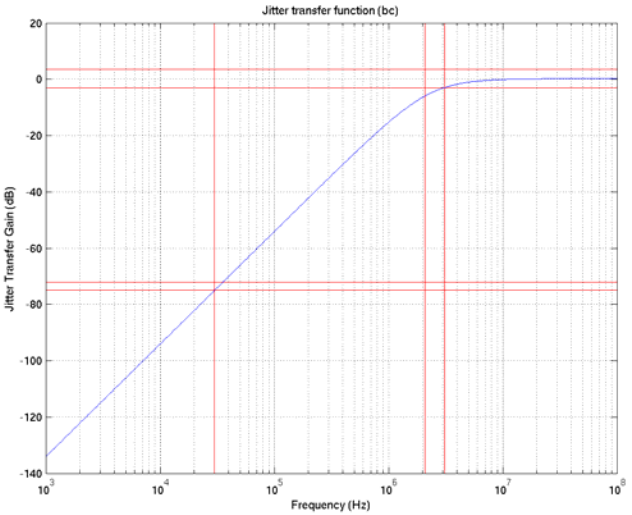
Using the JTF to qualify SSC modulation

PMC-SIERRA
Enabling connectivity. Empowering people.

- Use the JTF to calculate the residual SSC jitter seen by a baseline SAS-2 CDR
- Simulate with worst-case and best-case matlab models of the JTF



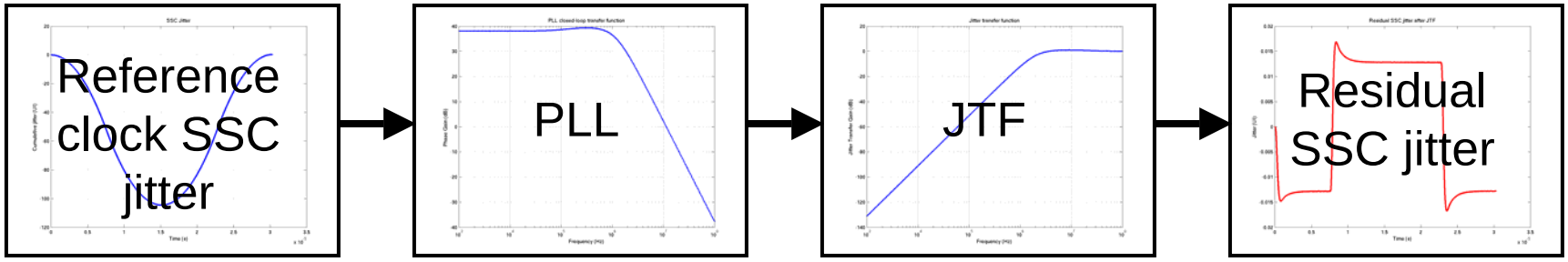
Worst-case JTF (-72dB @30kHz)



Best-case JTF (-75dB @30kHz)

Simulation Methodology

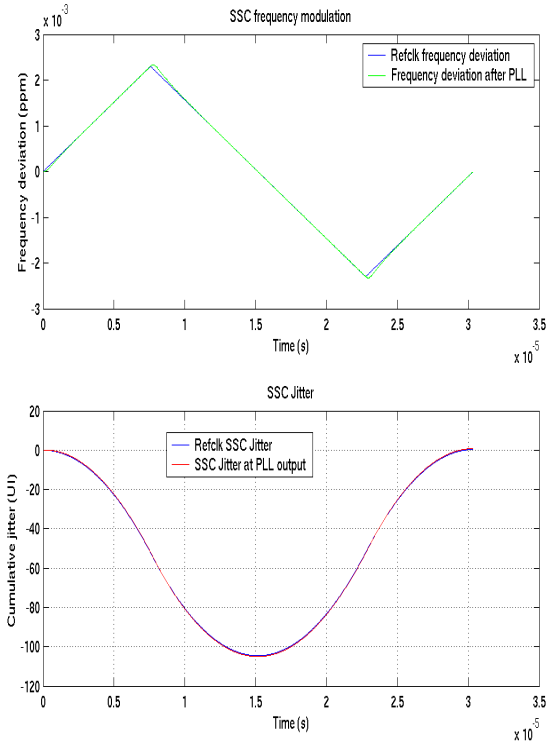
- Created SSC jitter profiles for Triangular, Hershey Kiss and Square Wave modulations.
- SSC-modulated 75MHz reference clock is passed through PLL with ~1.2MHz bandwidth, 40dB/decade roll-off and ~1.3dB peaking.
- Residual jitter is obtained by passing SSC jitter through JTF

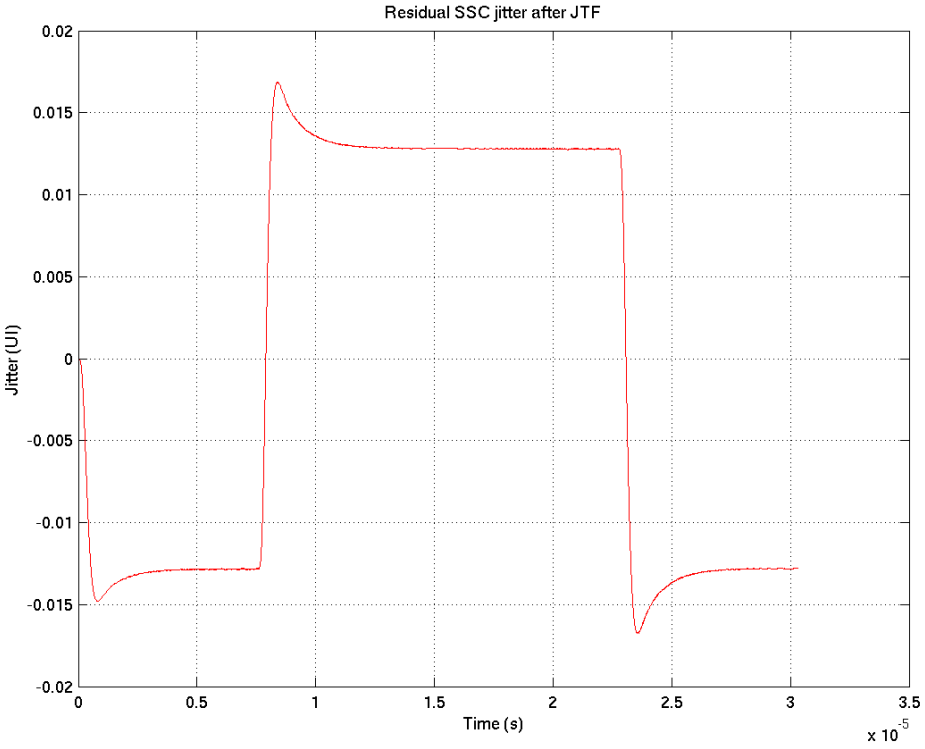


Triangular SSC Frequency Modulation and Jitter

PMC-SIERRA
Enabling connectivity. Empowering people.

- Results for worst-case JTF with triangular modulation

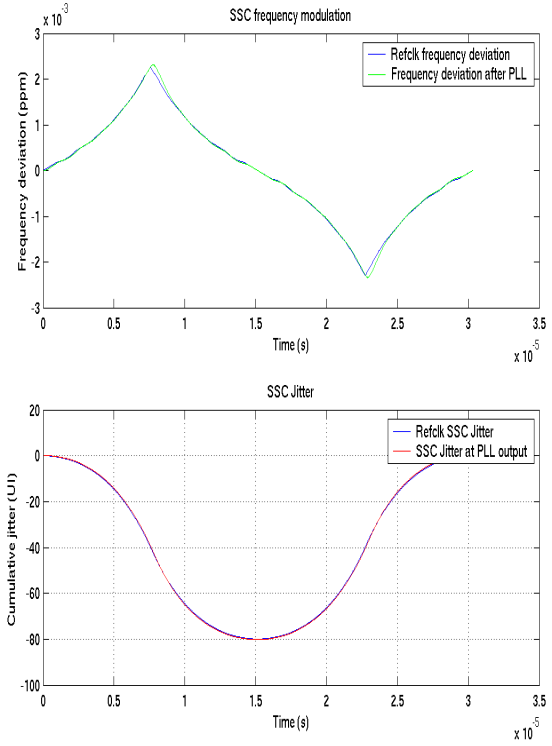


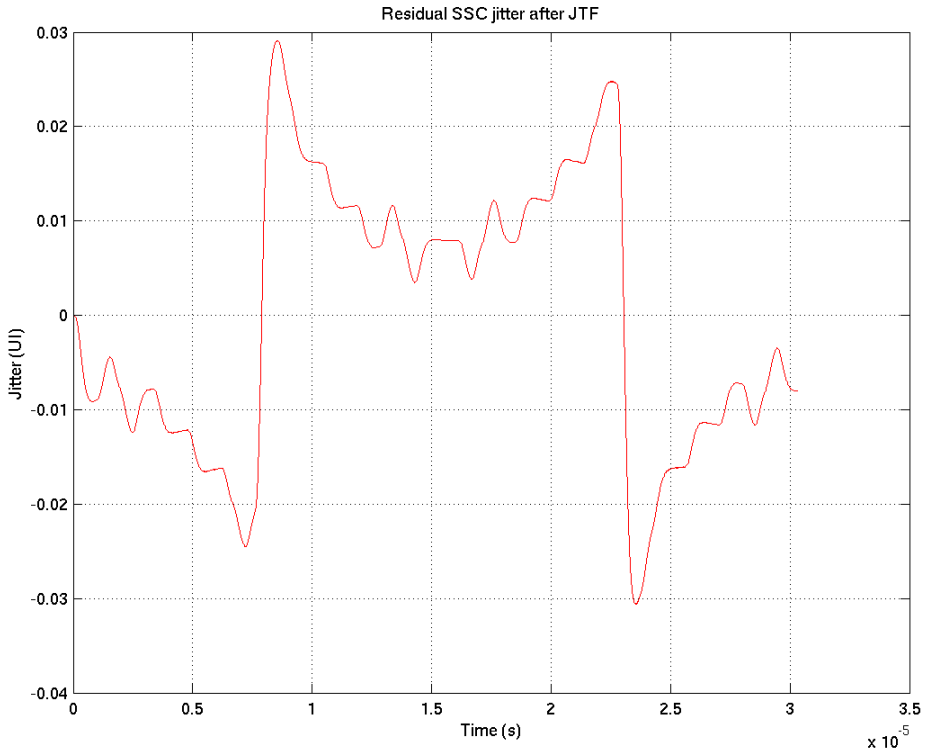


Hershey Kiss SSC Frequency Modulation and Jitter

PMC-SIERRA
Enabling connectivity. Empowering people.

- Results for worst-case JTF with HK modulation

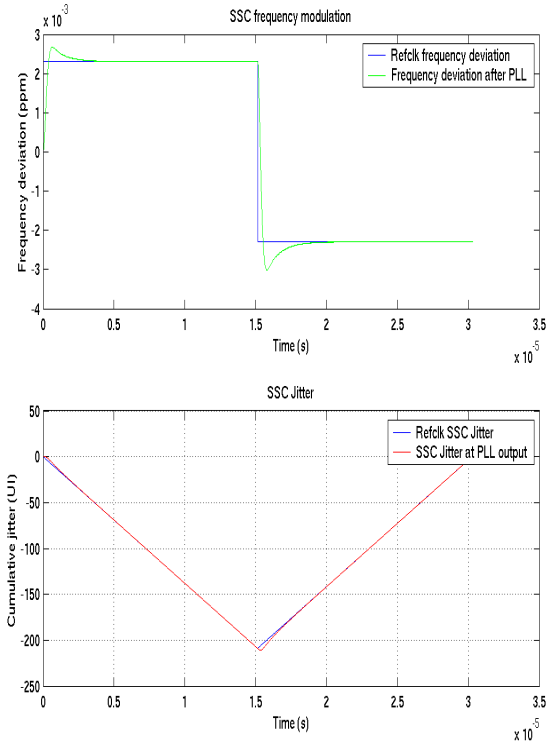


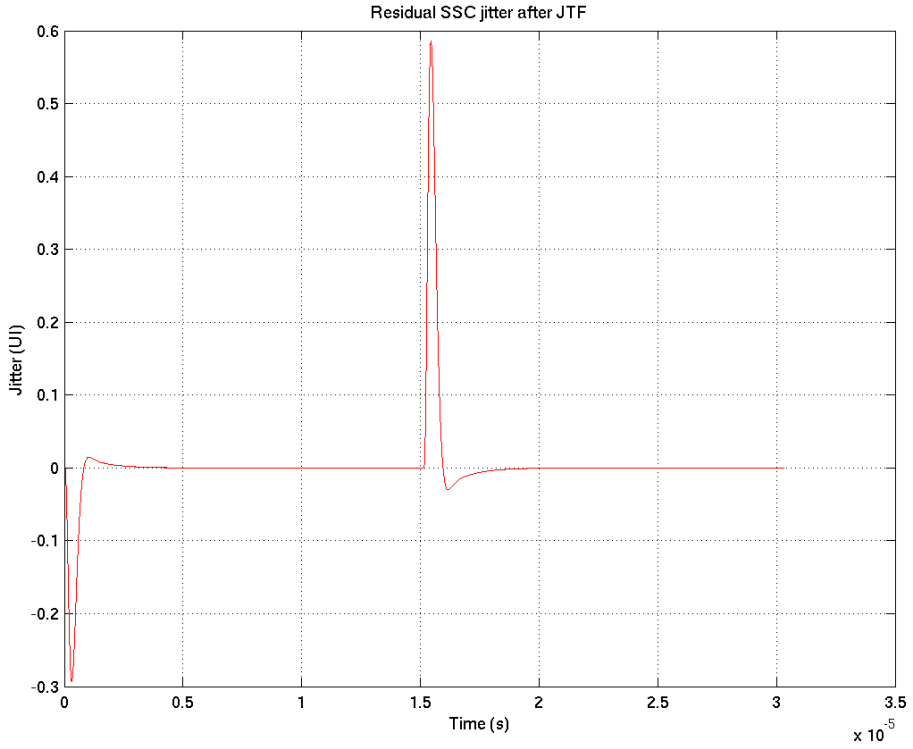


Square Wave SSC Frequency Modulation and Jitter

PMC-SIERRA
Enabling connectivity. Empowering people.

- Results for worst-case JTF with square modulation





Limitation of the JTF as CDR model

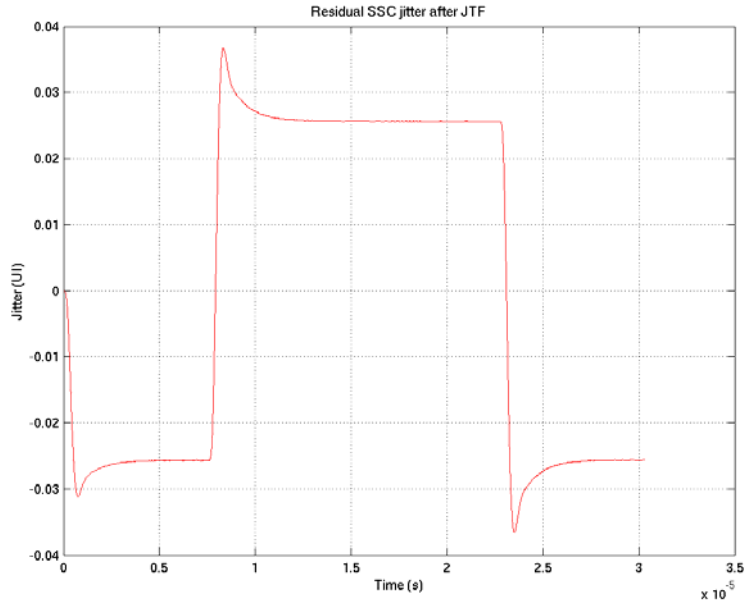
PMC-SIERRA
Enabling connectivity. Empowering people.

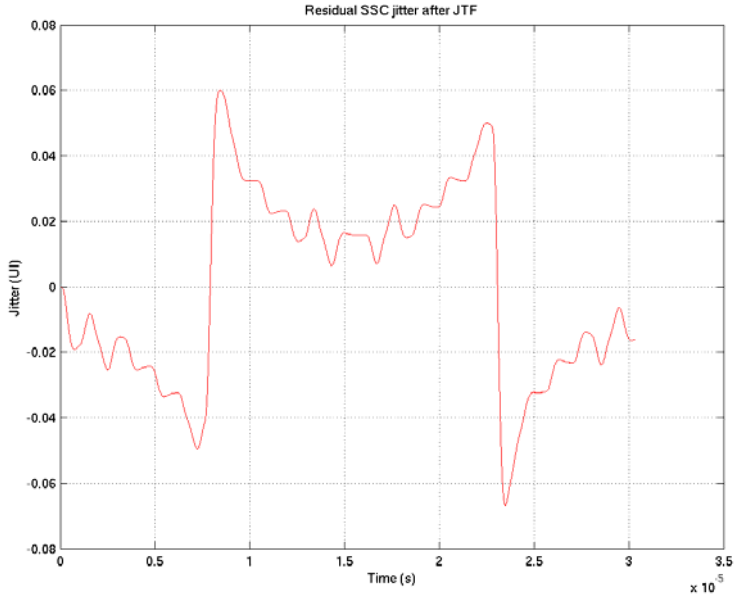
- According to the 6G PHY spec (07-339r7), the JTF must be calibrated using D24.3 pattern (110011…). This corresponds to a transition density of 0.5.
- When testing with CJTPAT, the transition density drops to ~0.3 in the long low frequency sequences
  - Can worst-case data have even lower transition densities?
- In most CDR architectures, gain is proportional to the transition density
  - A CDR that matches the JTF response with D24.3 will have its gain reduced by half when receiving a worst-case pattern
  - SSC residual jitter will increase by ~70% for CJTPAT

Limitations of the JTF as model of CDR

PMC-SIERRA
Enabling connectivity. Empowering people.

- Impact of reduced gain on CDR residual jitter
  - Residual jitter doubles for pattern density of 0.25UI
  - Illustrated for triangular and Hershey Kiss modulations





Residual SSC Jitter Summary

PMC-SIERRA
Enabling connectivity. Empowering people.

- Summary of SSC residual jitter results
  - When taking transition density into account, residual jitter from Hershey Kiss modulation eats up a fair part of the link jitter budget

Pattern	Peak-to-Peak Residual SSC Jitter (UI)		
	Best-case JTF	Worst-case JTF	Worst-case JTF with transition density = 0.3 (to emulate CDR with CJTPAT)
Triangular	0.024	0.034	0.059
Hershey Kiss	0.043	0.061	0.107
Square Wave	0.82	1.17	2.02

Should we change the JTF to reflect CDR performance with a worst-case pattern?

Theoretical Value of Residual Jitter

PMC-SIERRA
Enabling connectivity. Empowering people.

- Final value of the residual jitter when the jitter produced by a frequency ramp is filtered by the JTF

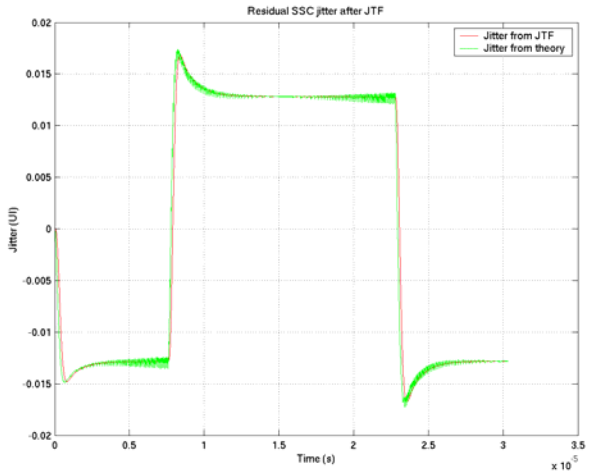
$$\lim_{t\to\infty} Jitter(t) = \lim_{s\to 0} s\,\frac{1}{s}\,\frac{frequency\_deviation\_rate}{s^2}\left(\frac{s^3\cdot Tb + s^2}{s^3\cdot Tb + s^2 + s\cdot K\cdot Ta + K}\right) = \frac{frequency\_deviation\_rate}{K}$$

Phase is integral of frequency

Frequency ramp (triangular modulation)

JTF

- Comparing residual jitter for triangular SSC profile
  - Response from JTF (red)
  - Response from above formula with slope averaged over 80 bits to remove refclk spurs (green)



How much SSC jitter is too much jitter?

PMC-SIERRA
Enabling connectivity. Empowering people.

- Tentative link budget for discussion

	Source Transmitter & PLL	Reference Channel	Target Receiver & PLL	Total	Comments
Random Jitter (RJ)	0.15		0.15	0.21	Total calculated as root sum of squares
Bounded Non-Compensable Jitter (BNCJ)	0.15	0.05		0.2	Includes: - Residual SSC jitter - Duty-cycle distortion - Periodic Jitter (from supply noise, etc.) - Crosstalk - Common-mode to differential conversion *Excludes:* *- Data Dependent Jitter*
Data-Dependent Non-Compensable Jitter (NCDDJ)		0.38		0.38	ISI and reflections that can't be corrected by 3-taps DFE Simulated with stateye v5: - SAS-2 reference channel - 2dB pre-emphasis - No DJ or RJ - 8b10b encoding
Receiver Margin (RMJ)			0.2	0.2	Includes: - Samplers sensitivity - Quantization effects - Device mismatches
Total Jitter	*0.3*	*0.48*	*0.35*	***0.99***	

Note: Transmitter jitter measured at near end

Tentative link budget considerations

- Is 0.05 UI (8 ps) a good number for channel non-compensable jitter?
  - Crosstalk
  - Common-mode to differential conversion
  - Reflections
- Is 0.20 UI (33 ps) a sufficient margin for the receiver?
  - Should we tighten other specs for more receiver margin?
- Can we gain margin by increasing pre-emphasis?
  - How accurate are the stateye results?

Tx Pre-Emphasis (dB)	NCDDJ for 3 taps DFE (UI)
0	0.4
2	0.38
3	0.4
6	0.39

Tentative SSC Specifications

- CDR considerations
  - SSC modulation shall not exceed the +/-2300ppm range
  - SSC modulation shall not cause the transmit jitter to exceed the jitter spec when filtered through the JTF
    - SSC slope has a direct impact on residual jitter and thus does not need to be specified explicitly
- Average frequency shall be within *TBD* ppm
  - Max ALIGNs insertions/deletions is not a limitation (2/512 gives 3900ppm)
- Average deviation over any 16.67us period is not an issue
  - FIFO depth typically larger than 480 bits (~4800ppm)