What is Clock Jitter

• Jitter is, “The deviation of an event timing relative to its ideal value”
  • Event? - defined by specific type of jitter
  • Ideal value? - event timing on an ideal clock, often estimated from average value of the event

• Jitter definitions:
  • Period Jitter (Covered in Part 1)
    • Deviation of the clock period from averaged value
  • Timing Interval Error (TIE) Jitter and Phase jitter (Part 2)
    • Error in edge location relative to an ideal clock
  • Cycle-to-Cycle Jitter (Part 3)
    • Deviation of the difference of periods of two consecutive clock cycles
  • Long Term or Multi-Cycle Jitter (Part 3)
    • Deviation of the durations of multiple cycles from the averaged value
    • Also known as long term jitter or accumulated jitter
Cycle-to-cycle Jitter (C2C)

- Cycle-to-cycle jitter: the difference of one period and its adjacent one
  - Event: Three consecutive rising or falling edges
  - Ideal value = average C2C

\[ J_{CC+}(k) = T_k - T_{k-1} \]
\[ = t_k - 2t_{k-1} + t_{k-2} \]
\[ = TimeJ(k) - 2.TimeJ(k-1) + TimeJ(k-2) \]

\[ J_{CC-}(k) = T_{k-1} - T_k \]

Relate C2C to TIE or Timing Jitter
About C2C Jitter

- C2C jitter is the difference of two adjacent clock period and it dominated by the high frequency jitter

- Can be measure by real-time oscilloscope

- C2C jitter is not sensitive to low frequency jitter or slow frequency modulation of oscillator frequency
  - Often Used to specify jitter intrinsic jitter performance of spread spectrum clocks

- C2C jitter is not the same as “Cycle Jitter”
  - Cycle Jitter is the same as “Period Jitter”
C2C Jitter in a Spread Spectrum Clock

- C2C jitter changes little with spread spectrum clock (SSC) mode enabled or disabled
- C2C jitter is not sensitive to low frequency phase noise

SiT9001-125MHz SSXO with 2% down spread

Spread Spectrum Disabled
C2C jitter 17ps max

Spread Spectrum Enabled
C2C jitter 17ps max
Period Jitter in a Spread Spectrum Clock

- Period jitter *changes significantly* when SSC enabled.
- C2C jitter is the difference of two adjacent periods and it *remains steady* with slow SSC frequency modulation.

*SiT9001-125MHz SSXO with 2% down spread*

Spread Spectrum Disabled

Spread Spectrum Enabled

Period jitter 1.63 ps rms

Period jitter 49 ps rms with SS
Jitter Definitions and Terminology

Long Term Jitter (LTJ)

• Long term jitter: variations of timing intervals between the first edge and the last edge of N consecutive clock cycles.
  • Also known as “accumulated jitter” or “N-cycle jitter”
  • Can be specified by accumulation time of N-cycle, for example:
    • LTJ@100 μs for 100 MHz clock means N = 10,000
    • LTJ@10 μs for 62.5 MHz clock means N = 625

\[
LTJ_{N\text{-cycle}} (i) = T_{N\text{-cycle}} (i+1) - T_{N\text{-cycle}} (i)
\]
Jitter Definitions and Terminology

Long Term Jitter (LTJ)

Long Term Jitter: sensitive to low frequency phase noise integrated over long accumulation time

\[ LTJ_{N\text{-cycle}}(i) = T_{N\text{-cycle}}(i+1) - T_{N\text{-cycle}}(i) \]

\[ = (t_{i+N} - t_i) - N \times T_C \]

\[ = \text{TimeJ}(i + N) - \text{TimeJ}(i) \]

\[ = \sum_{j=i}^{N+i-1} J_{\text{PerJ}}(i) \]

Ideal value = Number of cycles (N) * average period (T_C)

Relate LTJ to TIE or Timing Jitter

Relate LTJ to Period Jitter

• Long term jitter: sensitive to low frequency phase noise integrated over long accumulation time
Observe LTJ on Real Time Scope

- Set “Trigger Delay” to observe 100 μs LTJ of a 125 MHz clock

Jitter increases with accumulation time

SiT9001-125 MHz SSXO with spread spectrum disabled
LTJ Measurement Setup with Real-Time Oscilloscope

**Setup:**
Direct connection to oscilloscope
50Ω loading to the oscillator output

• Measure LTJ with Real Time Oscilloscope
  • Use oscilloscope with low time base error (< 0.5 ps rms)
  • Optimize oscilloscope settings to reduce measurement error
  • High sampling rate increases the sample size and slows down measurement
LTJ Measurement Setup with Time Interval Analyzer (TIA)

**Setup:**
Direct connection to TIA
50Ω loading to the oscillator output

- **SiTime jitter measurement setup**

- **Measure LTJ with TIA**
  - Based on counter-timer approach
    - Can achieve high equivalent time base resolution in sub-ps range
  - Sampling rate on input clock signal much lower than real-time scope
  - Achieve faster LTJ measurement for long accumulation time
  - Can also be used for serial link diagnostics and compliance testing
Measure LTJ on TIA

- Set $N = 2500$ to measure LTJ@100 $\mu$s on a SiT8208-25 MHz clock

$$N \times T_c = 2500 \times \frac{1}{25E6} = 100 \ \mu\text{s}$$

Accumulation Time

*25 MHz Clock Period*

RMS and P-P LTJ@100 $\mu$s

TIA Model: Wavecrest SIA-4000
Who cares about LTJ

- Applications that require synchronization of timing events over relatively long time interval or many clock cycles
  - Analog and digital video
  - DDR for achieving phase locking in DDR interface
Summary

- C2C jitter reflects the high frequency jitter of the clock signal and is not sensitive to slow frequency modulation of a spread spectrum XO

- Long term jitter, defined by accumulation time or N-cycle, is sensitive to low frequency phase noise

- Applications care about LTJ when multiple timing events need to be synchronized over relatively long time interval
Contact Information

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