Jitter Measurement Metrics
IEEE 802.3bs electrical ad-hoc
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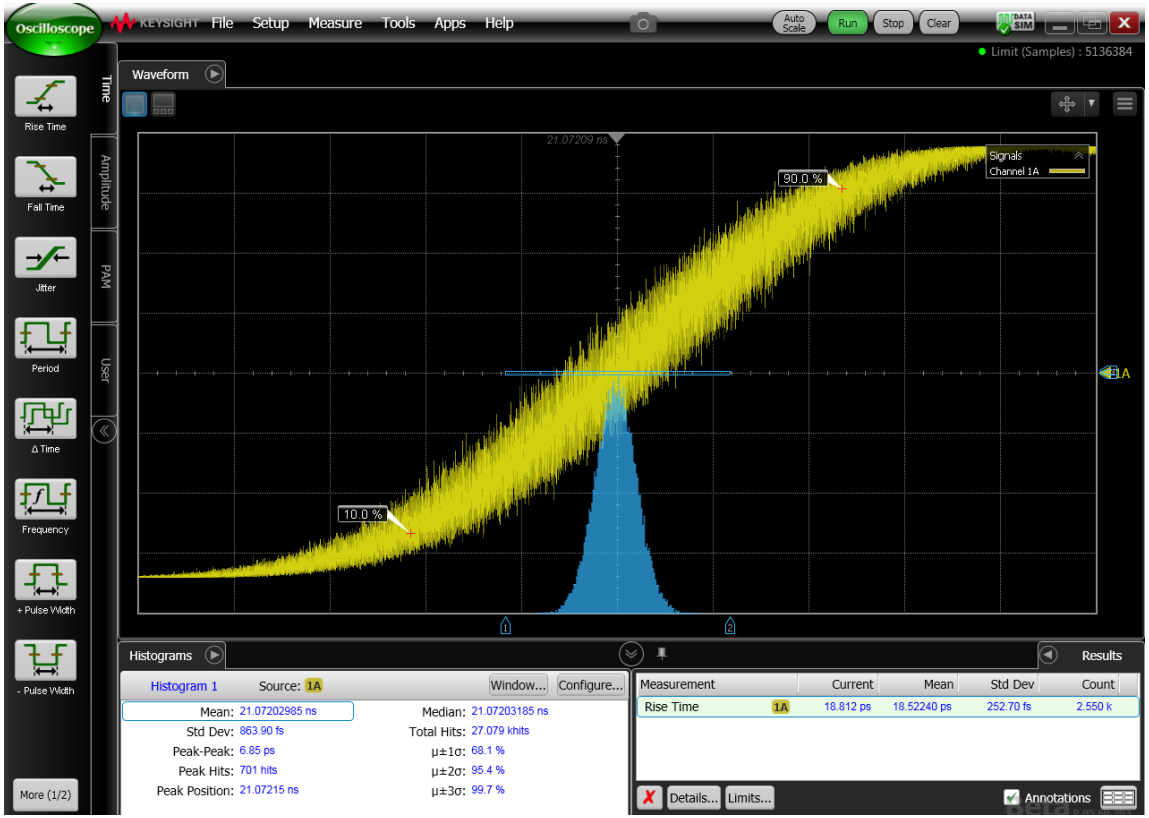
KEYSIGHT TECHNOLOGIES

Background / Goals

- At the Huntington Beach meeting the topic of test times for J4 was discussed: Will the test times be reasonable?
- Today
  - What factors dictate test times
  - What methods can be employed to improve efficiency
  - What tradeoffs exist between speed and accuracy

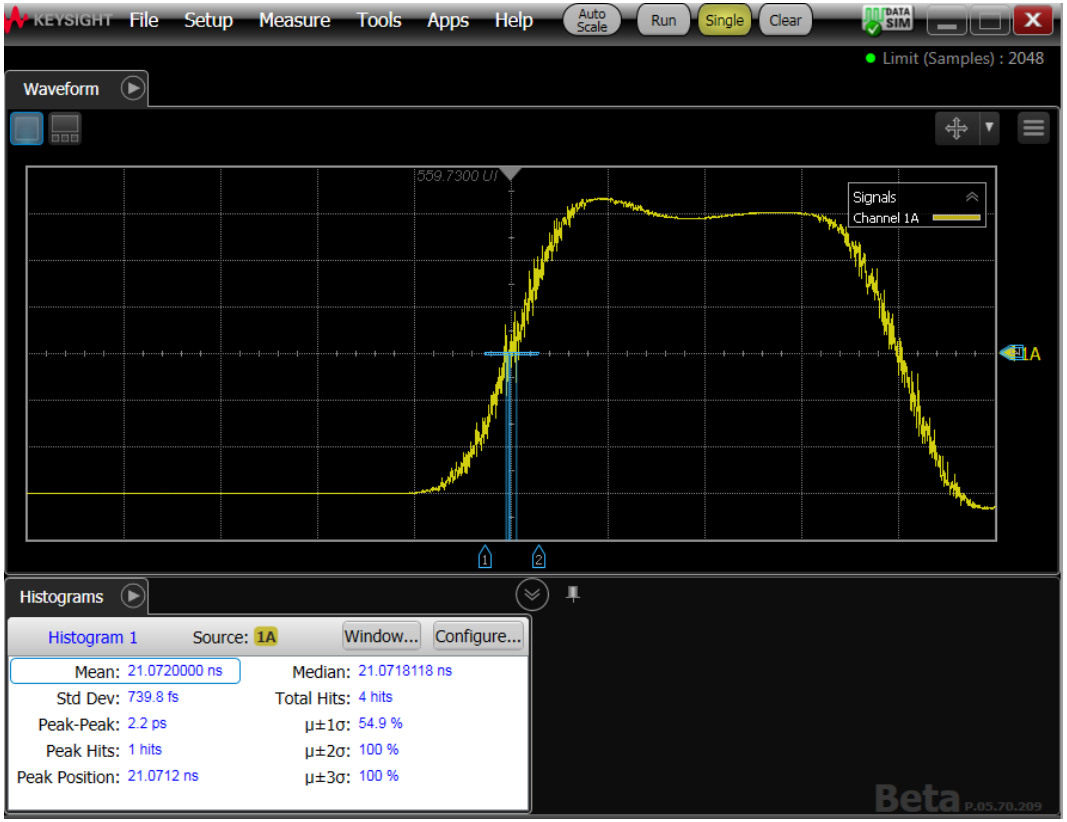
Start with the basic approach

- Collect histogram data at a narrow vertical slice of the waveform edge
  - Histogram height kept low so that ‘spread’ is not influenced by the slew rate/rise time of the edge
- Continually collect waveforms to add to the histogram population until the size is adequate to extract statistics at the desired probabilities



Basic approach is highly inefficient

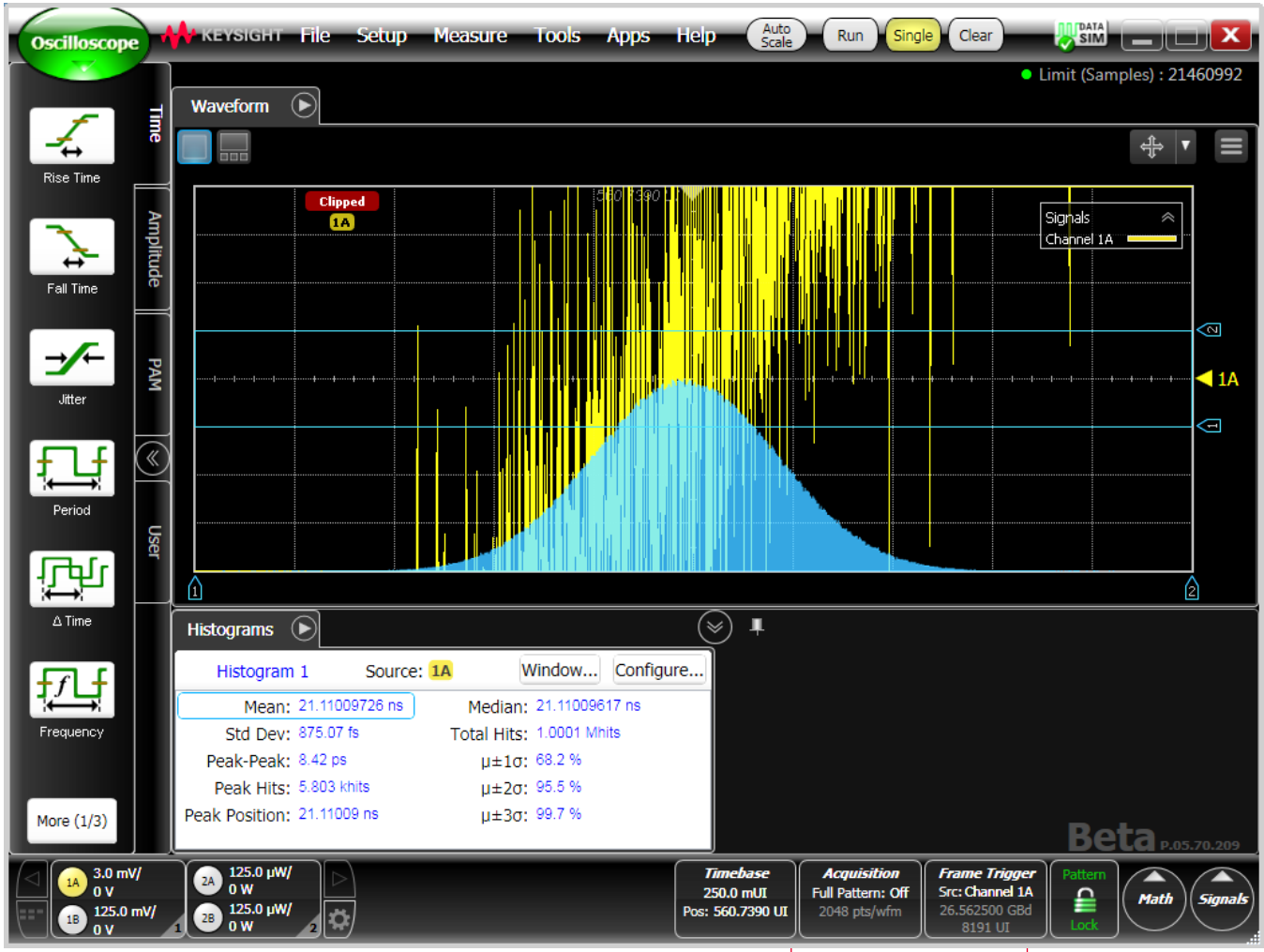
- Of the total number of samples collected, a very small percentage actually contribute to the histogram
- << 1% sampling efficiency (number of samples actually used is very small compared to the total number of samples collected)
- Several methods can be used to improve the effective sampling efficiency



Zoom in on the edge

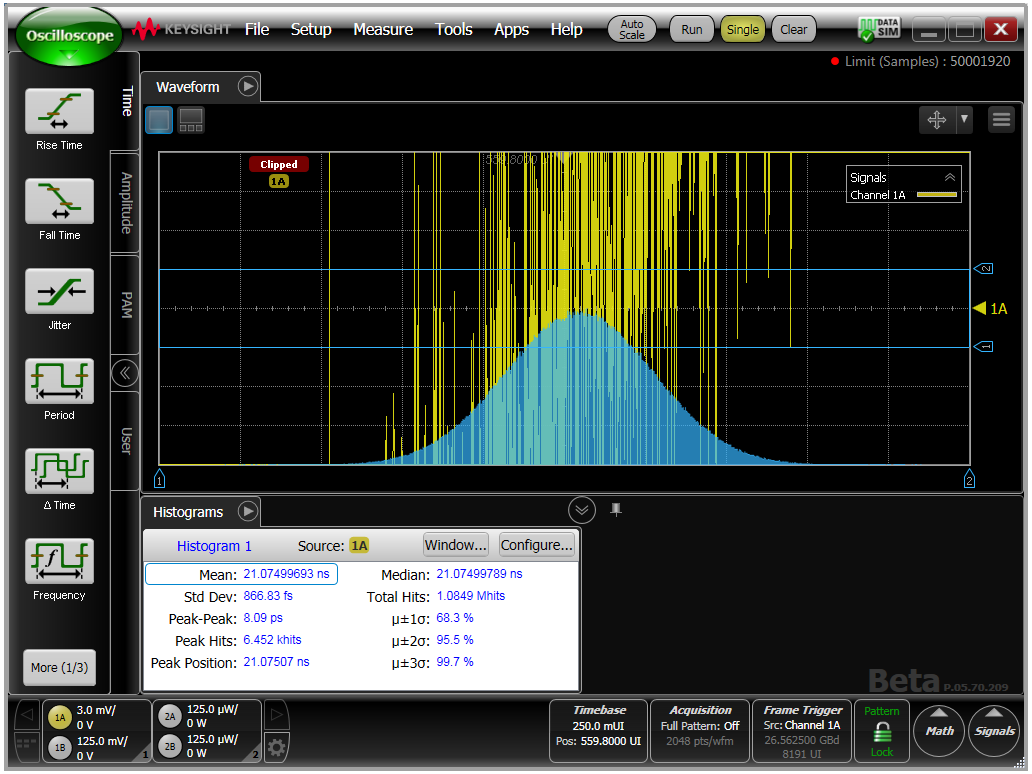
Higher percentage of total samples fall into the histogram window

- To acquire 1 million samples in the histogram slice, over 20M samples are collected
- ~ 5% efficiency



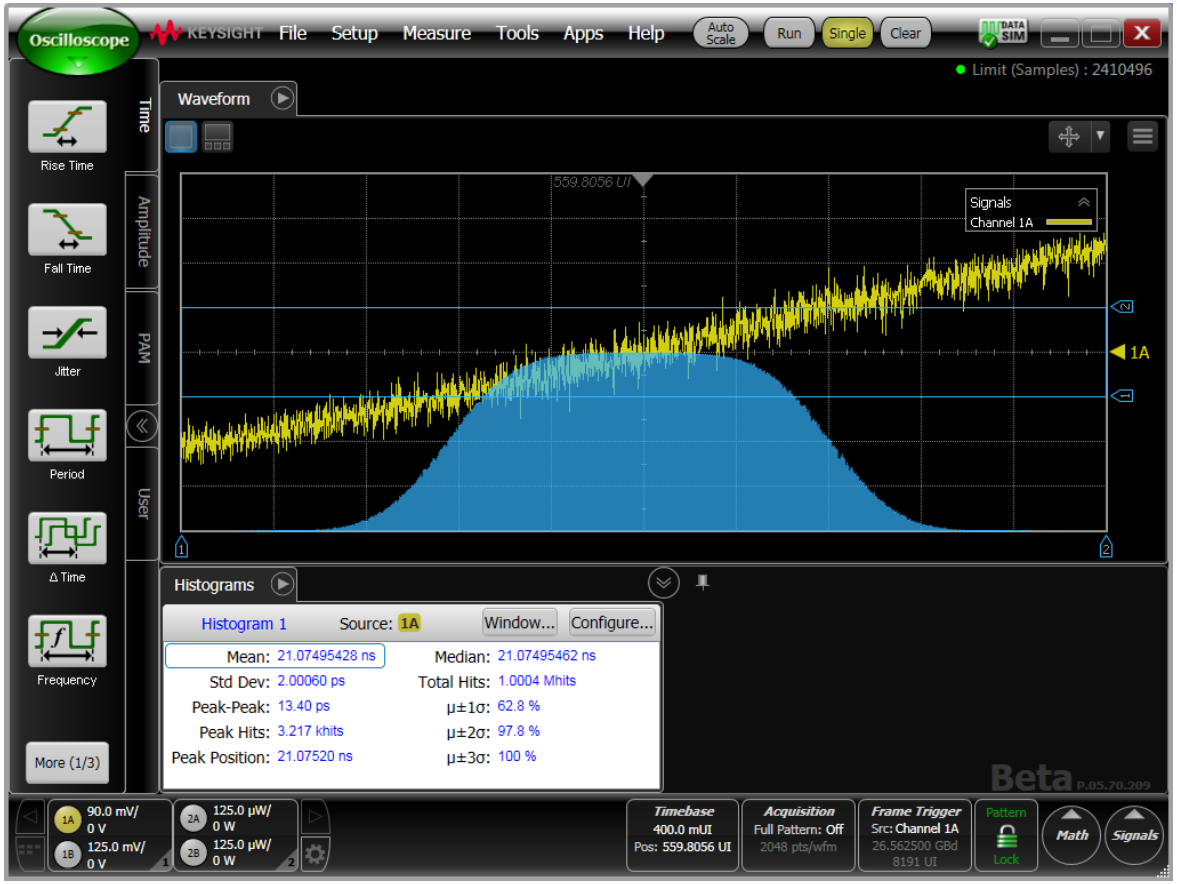
Sampling efficiency depends on slew rate

- For a faster edge (~2.5X previous example) 1M samples in the histogram requires 50M total samples
- 2% efficiency
- Intuition: Consider the limits
  - Zero risetime: no samples ever observed
  - Infinite risetime, all samples fall within the histogram window



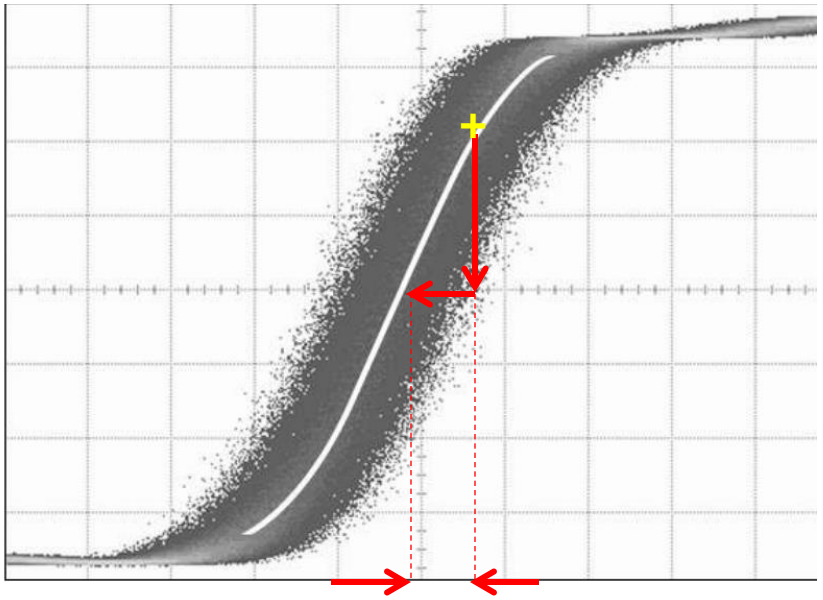
Efficiency improved by expanding the histogram height

- The key is to have as many of the overall acquired samples as possible to contribute to the histogram
- Obviously the histogram is now impacted by the slew rate
- Solved by slicing the histogram data into multiple vertically thin sub windows
- 2.4M samples acquired to have 1 million samples in the histogram (42% efficiency for this edge speed))



Edge model technique

- Only take samples at the expected edge crossing time
- If jitter is present, observed amplitude will deviate from expected crossing point amplitude
- Knowing the amplitude versus time function (essentially the shape of the edge), amplitude measurements are converted to edge positions
- Sampling efficiency approaches 100% (approximately 1-2 seconds required to synchronize to and identify pattern and create edge models)

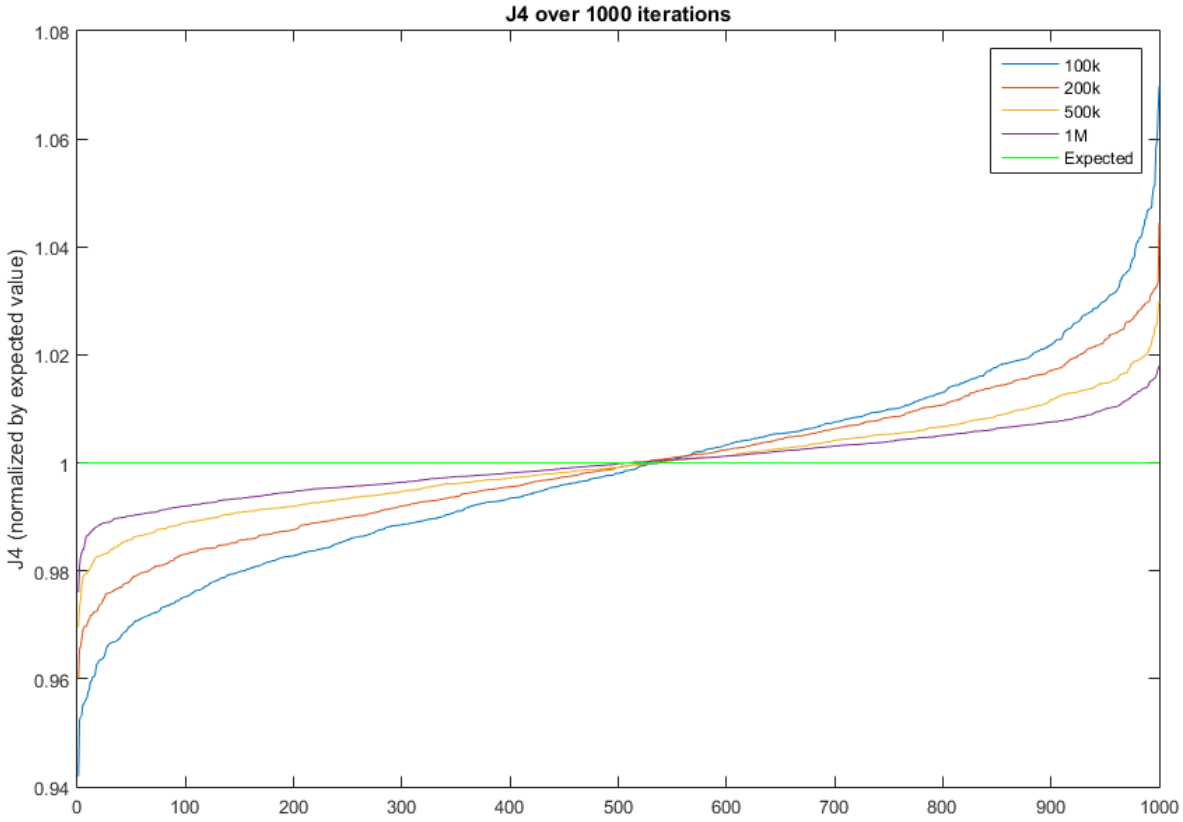


It is not intended that this method be incorporated into an IEEE standard, only that the standard does not preclude use of this technique

How many samples are required for J4?

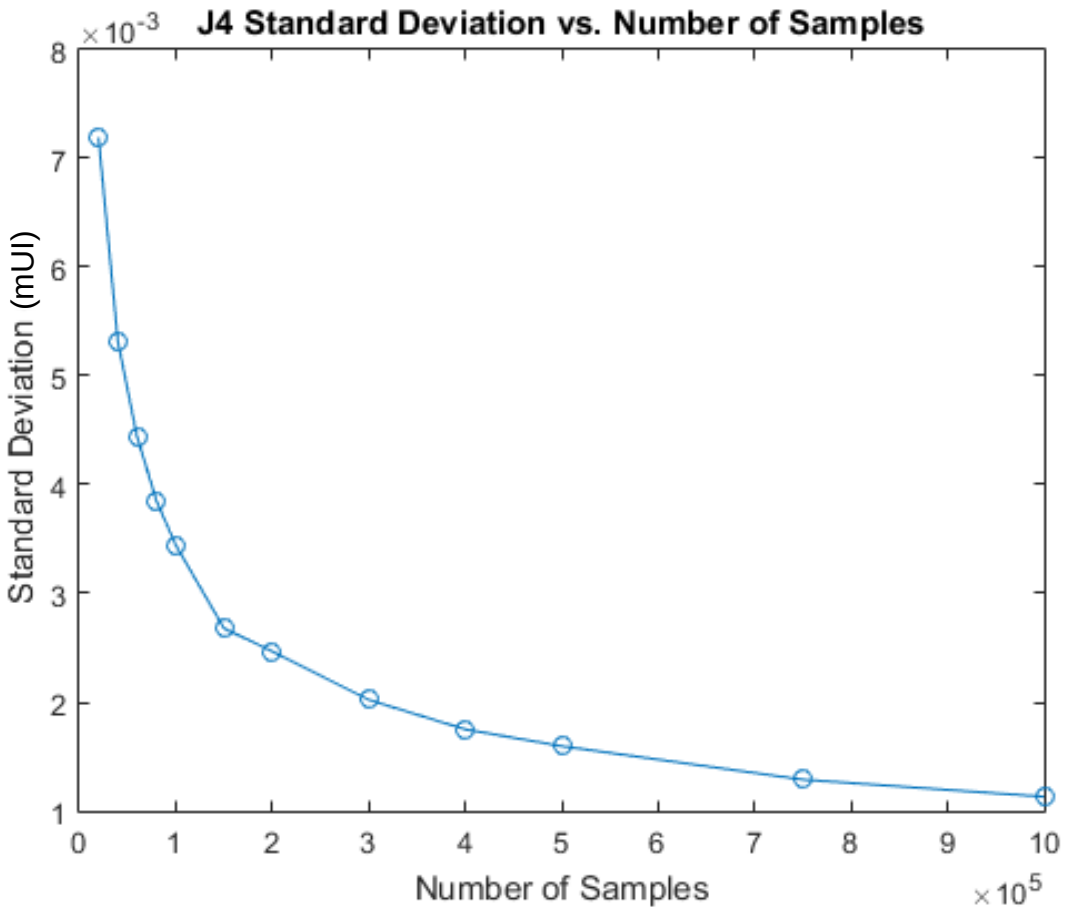
Observe a random signal with various populations and compute J4 (when signals also have deterministic jitter, tail to J4 is found faster)

- For each population (100K, 200K, 500K, 1M) J4 is determined 1000 times
- Each of the 1000 observed J4 values is normalized to the expected value and is ranked from low to high
- 1000 values (4 sets) plotted versus rank
- Example, for a 200K sample size, measured J4 value ranges from 96% to 104% of the expected value



Statistical error in mUI as a function of sample size

- Example: For 300K samples the standard deviation of the J4 measurement is ~ 2mUI
- Increasing the sample size reduces the measurement uncertainty but quickly has minimal impact



An alternative look at measurement uncertainty versus population (95% confidence interval)

- 100K samples
  - +4.1/- 3.5%
- 200K samples
  - +2.8/- 2.6%
- 400K samples
  - +2.0/- 1.9%
- 1M samples
  - +1.3/- 1.2%

NumSamples = 100000
95% Conf = 0.96453, 1.0405
J4 Std Dev = 0.019248

NumSamples = 200000
95% Conf = 0.97424, 1.0282
J4 Std Dev = 0.013787

NumSamples = 400000
95% Conf = 0.98138, 1.0195
J4 Std Dev = 0.009779

NumSamples = 1000000
95% Conf = 0.98799, 1.0128
J4 Std Dev = 0.0063205

J4 Std Dev scales with 2pi/sqrt(numSamples)

Some approximations of actual test times in seconds for various sample rates and histogram populations (one 17 ps edge, which has ~2% sampling efficiency)

100K, 200K and 1M sample histogram populations using 1% slice method

	100K samples	200K samples	1M samples
40 Ksa/s	125	250	1250
100 Ksa/s	50	100	500
250 Ksa/s	20	40	200

20% slice

100K, 200K and 1M sample populations using 20% slice method (~31% sampling efficiency for the 17 ps edge)

	100K	200K	1M
40 Ksa/s	8	16	80
100 Ksa/s	3	6	32
250 Ksa/s	<2	2.5	13

~100% efficiency

100K, 200K and 1M sample populations using targeted sampling

	100K	200K	1M
40 Ksa/s	3	5	25
100 Ksa/s	<2	<2	10
250 Ksa/s	<2	<2	4

Making estimates for different slice windows and edge speeds can be approximated by scaling results, but this is not exact

Our belief is that J4 might be accurately evaluated using 2 edges

Possible 6X improvement in test times

– Do we have real signals to validate either opinion?

Conclusions

- Jitter measurement times are highly dependent on
  - Sample rate
  - Methods to acquire data and resulting sampling efficiency
  - Required accuracy and subsequent populations
    - Consider this versus other measurement uncertainties