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Efficient ADC Testing Condition with Histogram Method

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Outline

- Objective
- ADC Test with Histogram Method
- Input Sine Wave and Sampling Frequency Relationship in ADC Histogram Test Method
  - ➢Sine Wave Histogram and Waveform Missing
  - ➢Metallic Ratio and Prime Number Ratio
- Conclusion

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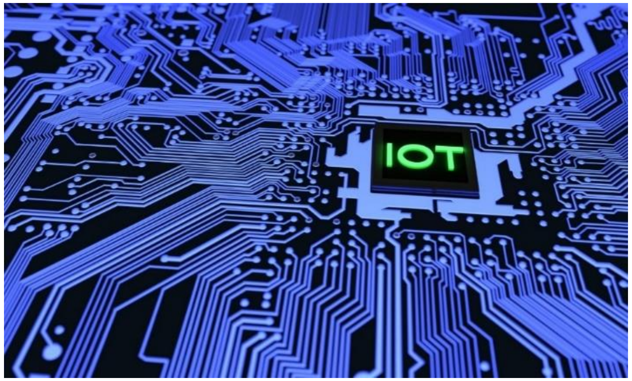
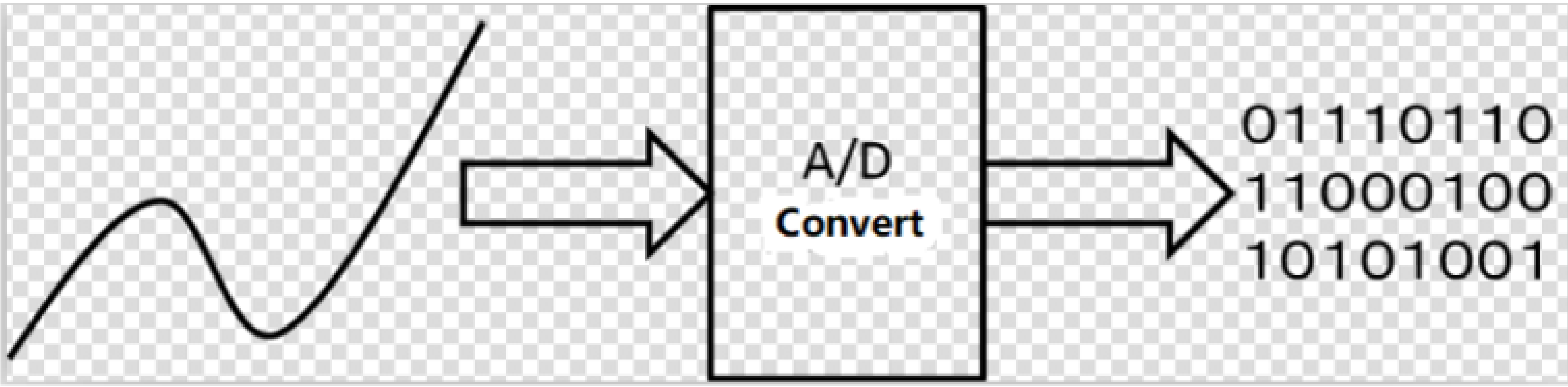
Background

IoT（Internet of Things）



The application of digital signal and analog signal conversion is very extensive.

- ◆ Analog signal (sound, light)
- ◆ Digital signal (Binary number)



High quality & Low cost test is required

Research Objective & Approach

Analog-to-Digital Converter (ADC)
Linearity Test

Test cost is proportional to test time

the low-sampling-rate high-resolution ADC
- low-speed sampling
- high-resolution

take a long time

This Work

Increasing
the sampling efficiency

Propose "short-time" Relationship Between Input Frequency and Sampling Frequency

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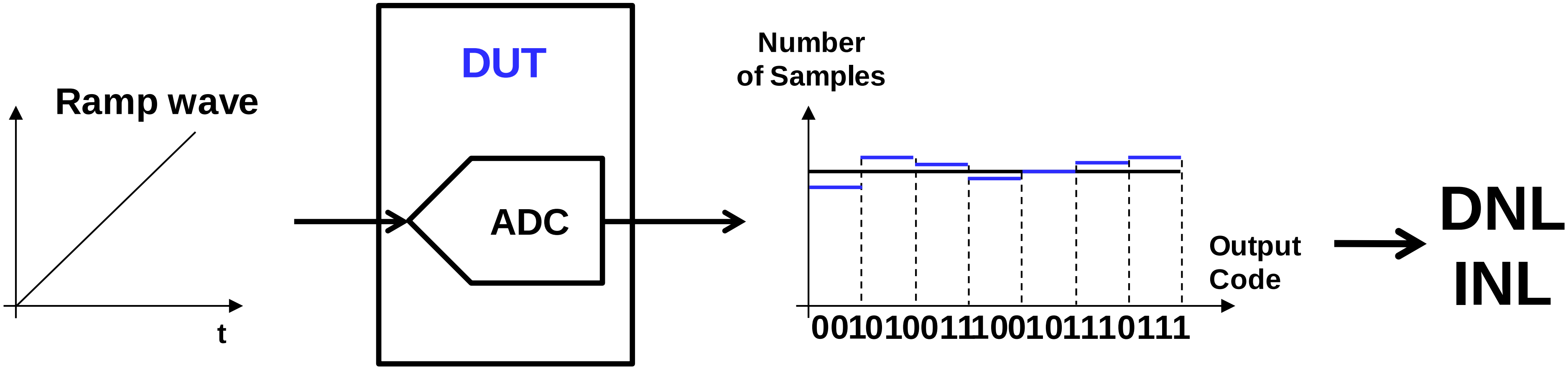
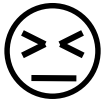
Conventional Linearity Testing 1

■Histogram method (Ramp wave input)

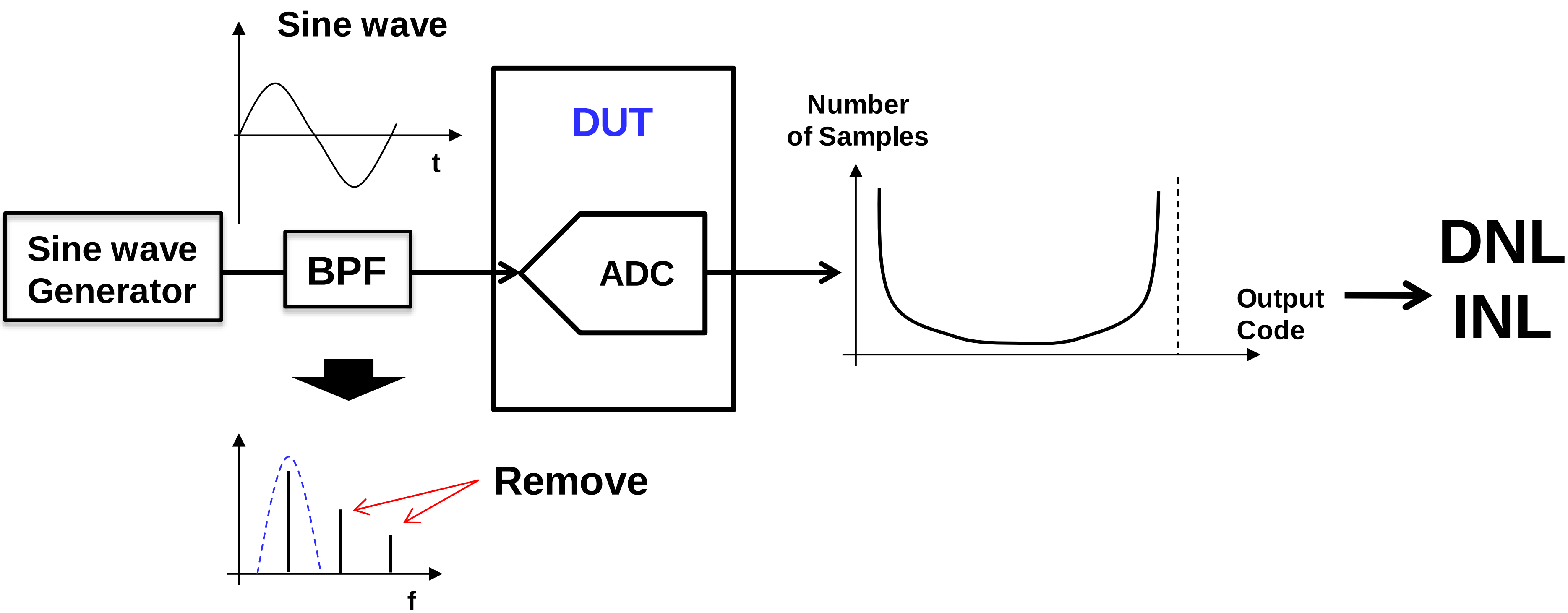


- ADC output histograms for all bins are equal if ADC is perfectly linear
- Highly linear ramp signal generation is difficult



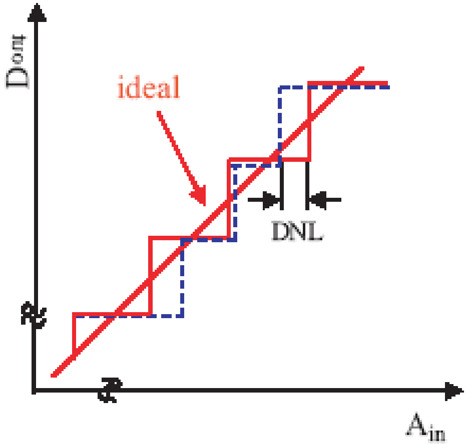
Conventional Linearity Testing 2

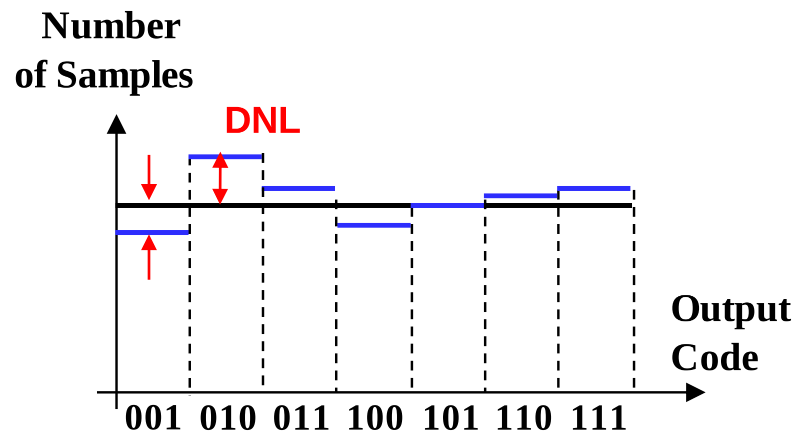
■Histogram method(Single sine wave input)

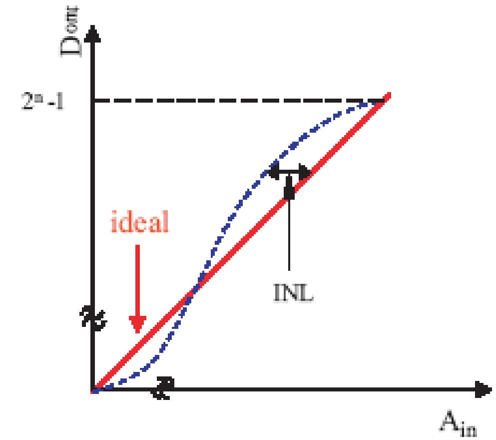


- The number of samples is small around the middle of output codes
- High accuracy sine wave can be generated using an analog filter

DNL & INL







- Important testing for ADCs

DNL : Difference between an actual step width and the ideal value

INL : Deviation from ideal conversion line

$$INL(k) = \sum_{i=1}^{k} DNL(i)$$

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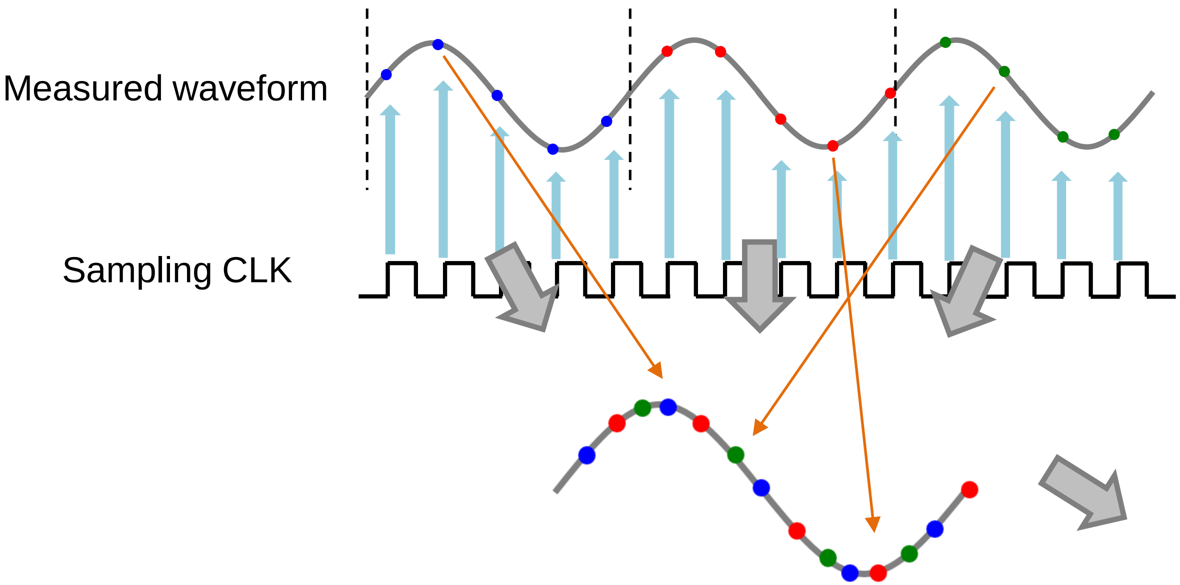
Sine Wave Histogram



Repetitive waveform sampled with asynchronous

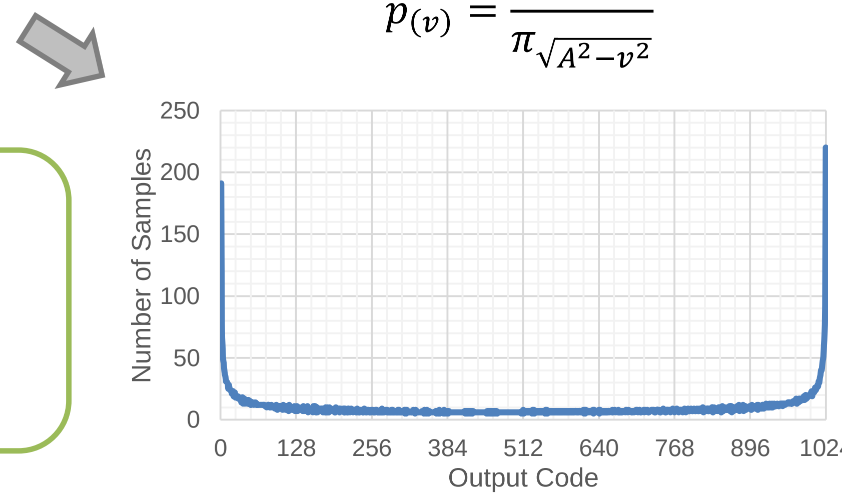
⇩

Compose a 1-period waveform

The sampled histogram is compared with the PDF.
The histogram is measured, DNL and INL are calculated.

Probability Distribution Function

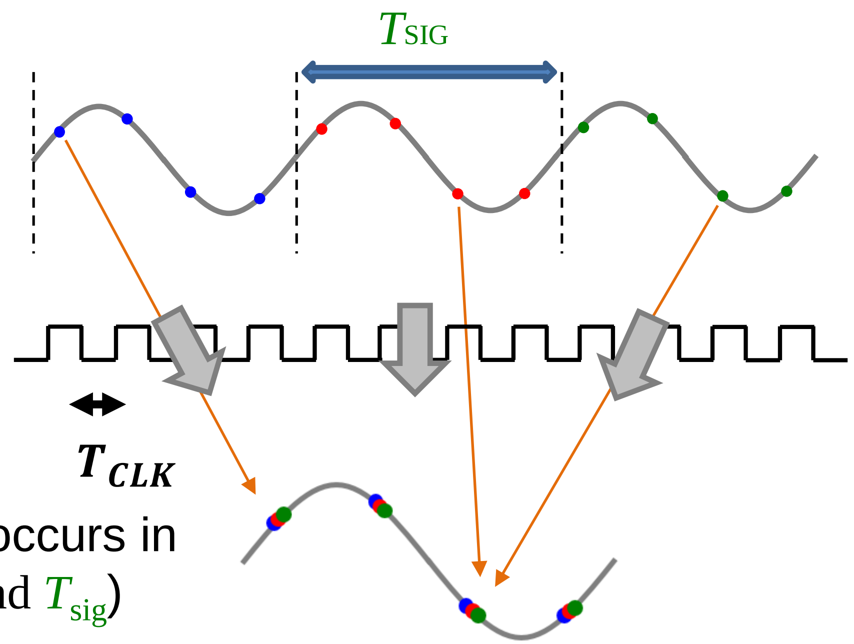
$$p_{(v)} = \frac{1}{\pi\sqrt{A^2 - v^2}}$$



Waveform Missing

Measured waveform

Sampling CLK

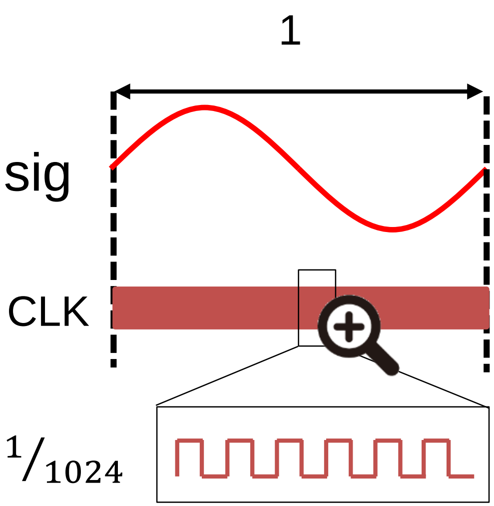


Waveform Missing occurs in Special ratio(T_{CLK} and T_{sig})

A large amount of data is required to reproduce the waveform ➡ Test time: long

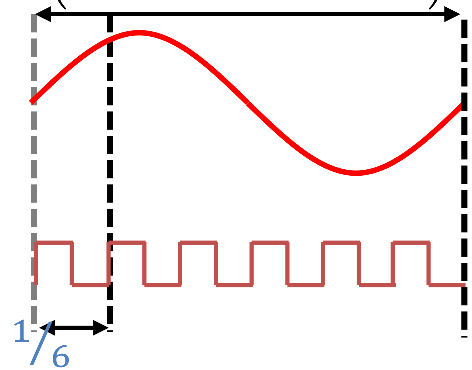
Waveform Missing

$f_{CLK} \gg f_{sig}$



$f_{CLK} \approx \frac{1}{\alpha} f_{sig}$

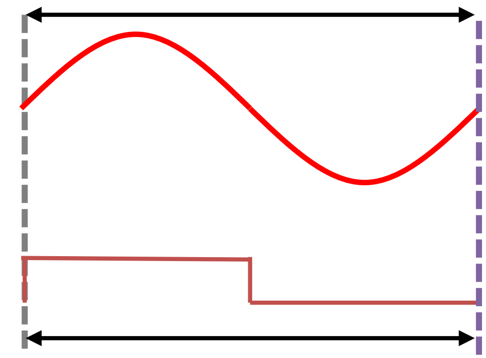
$\left(\alpha = 1, \frac{1}{2}, \frac{1}{3}, \frac{2}{3}, \cdots, \frac{1}{6}, \cdots\right)$

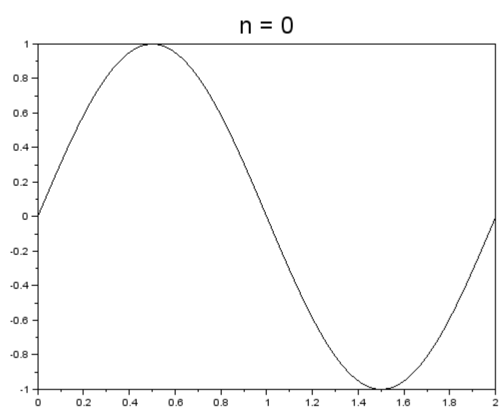


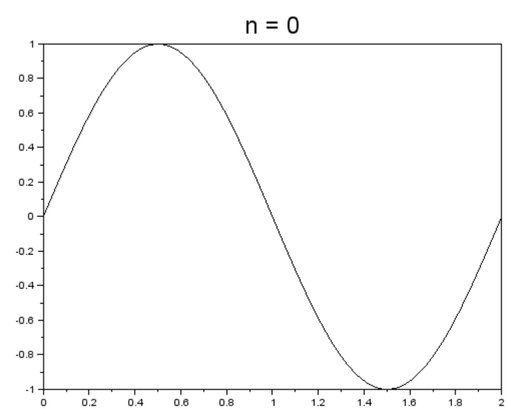
Special ratio

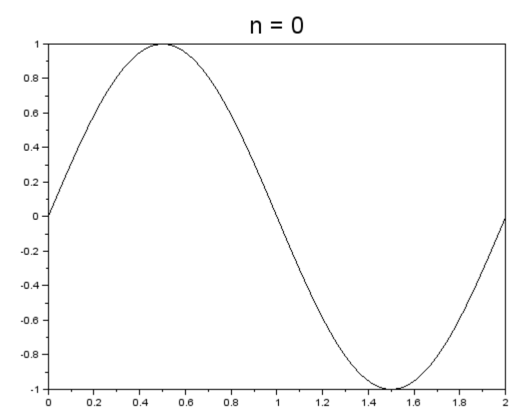
T_{CLK} and T_{sig}, f_{CLK} and f_{sig}

$f_{CLK} \approx f_{sig}$



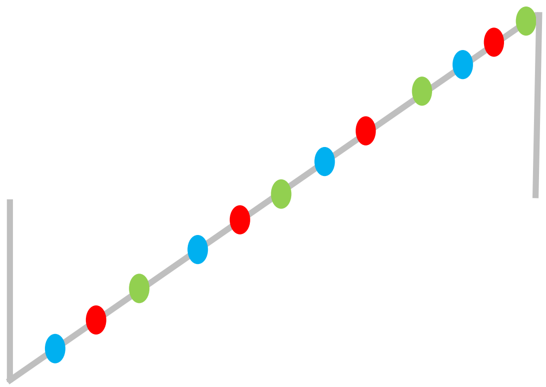




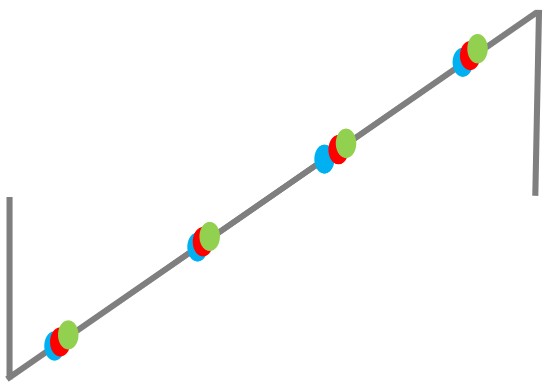


Yuto Sasaki, Yujie Zhao, Anna Kuwana and Haruo Kobayashi, "Highly Efficient Waveform Acquisition Condition in Equivalent-Time Sampling System", 27th IEEE Asian Test Symposium, Hefei, Anhui, China (Oct. 2018)

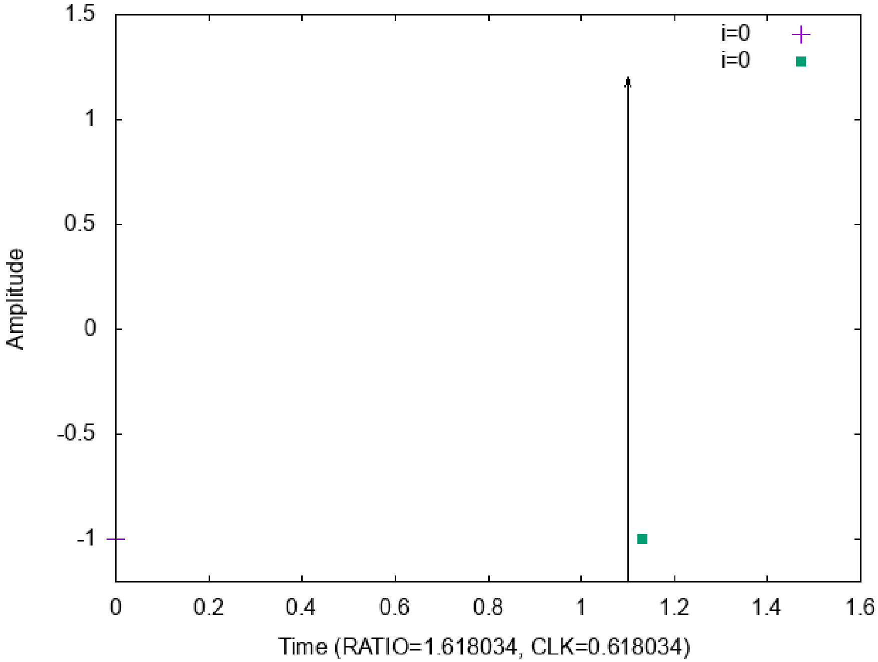
Waveform Missing

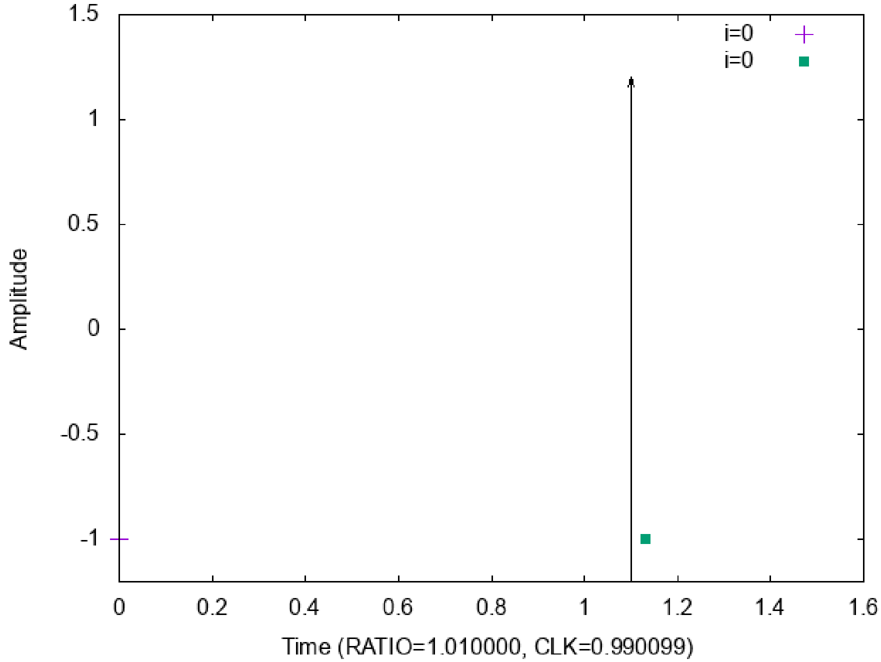


Normal situation



Waveform Missing

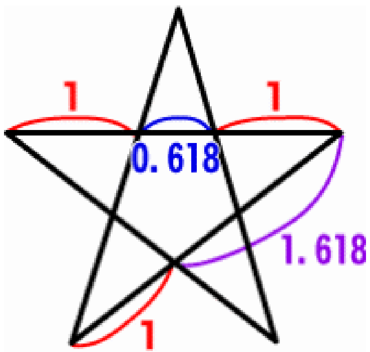


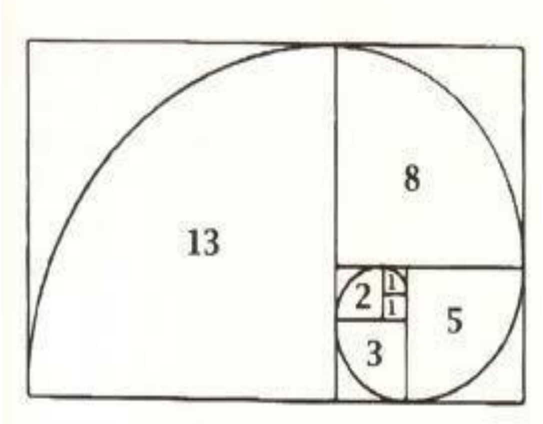


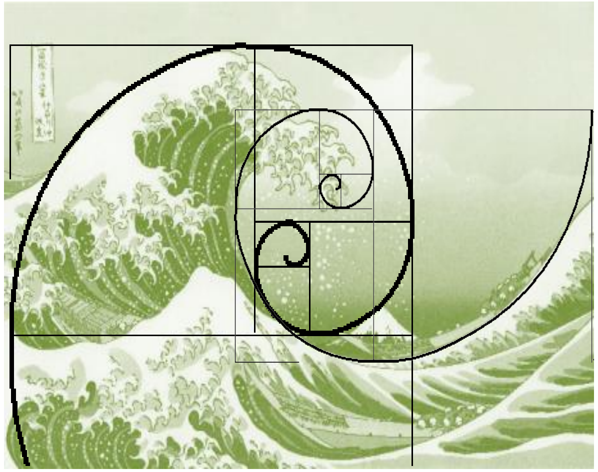
Golden Ratio

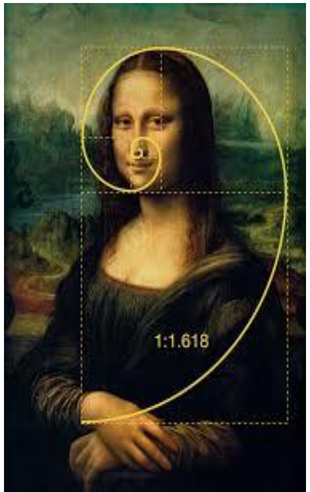
Golden Ratio : $\lim_{n\to\infty} \frac{F_n}{F_{n-1}} = 1.618033988749895 = \varphi$

The most beautiful ratio







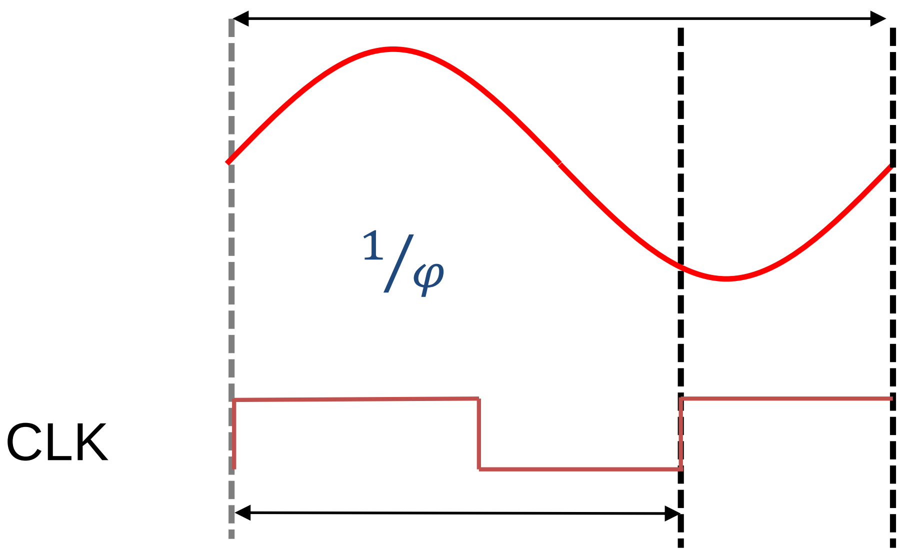


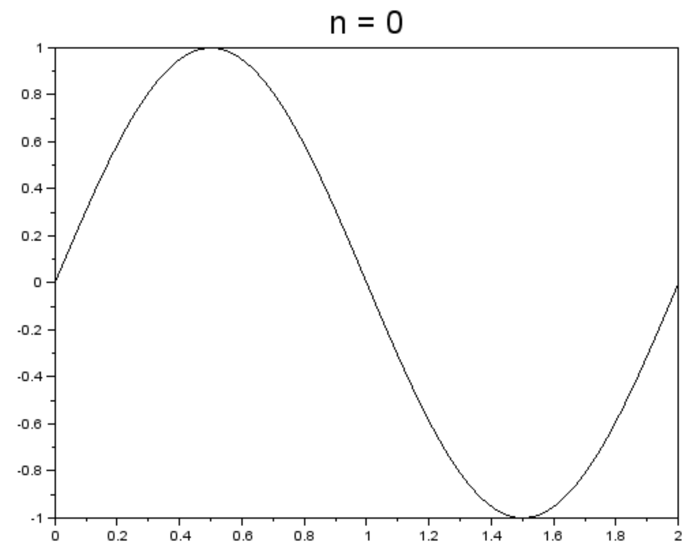
Golden Ratio

Golden ratio φ

$$f_{CLK} = \varphi \times f_{sig}$$

φ = 1.6180339887…





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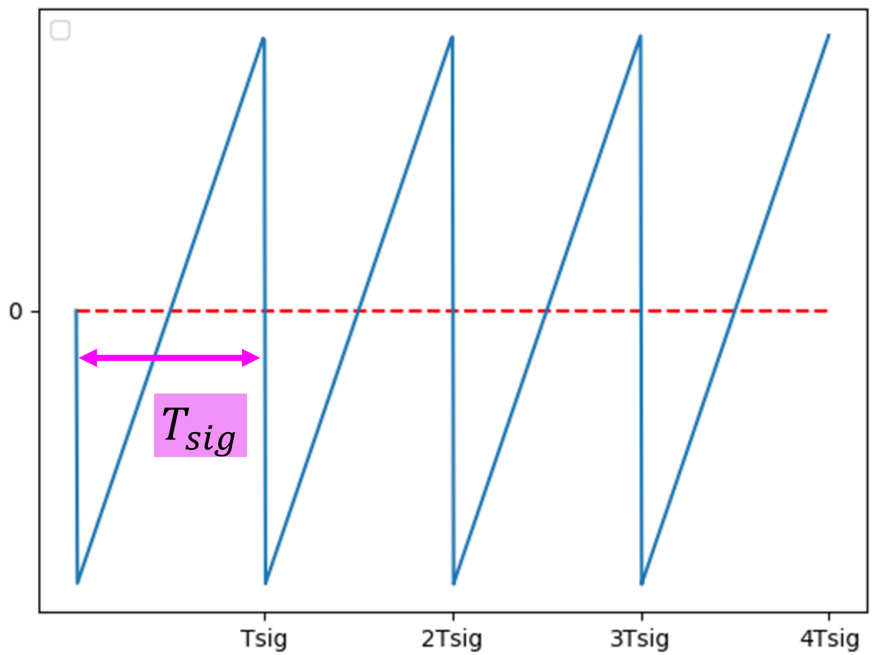
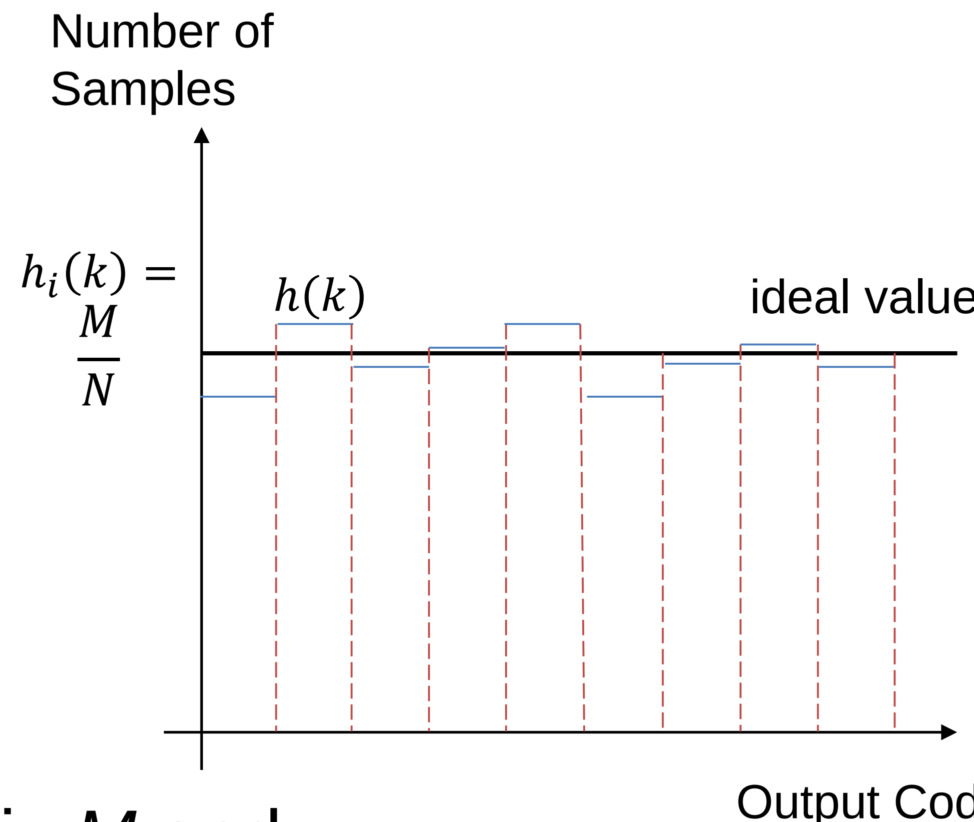
Metallic ratio

Golden Ratio : $\lim_{n\to\infty} \frac{F_n}{F_{n-1}} = 1.618033988749895 = \varphi$

n		Decimal	
0	1		
1	$\frac{1+\sqrt{5}}{2}$	1.6180339887…	Golden ratio ø
2	$1+\sqrt{2}$	2.4142135623…	Silver ratio
3	$\frac{3+\sqrt{13}}{2}$	3.3027756377…	Bronze ratio
4	$2+\sqrt{5}$	4.2360679774…	
…	…		
n	$\frac{n+\sqrt{n^2+4}}{2}$		

Histogram of Saw wave

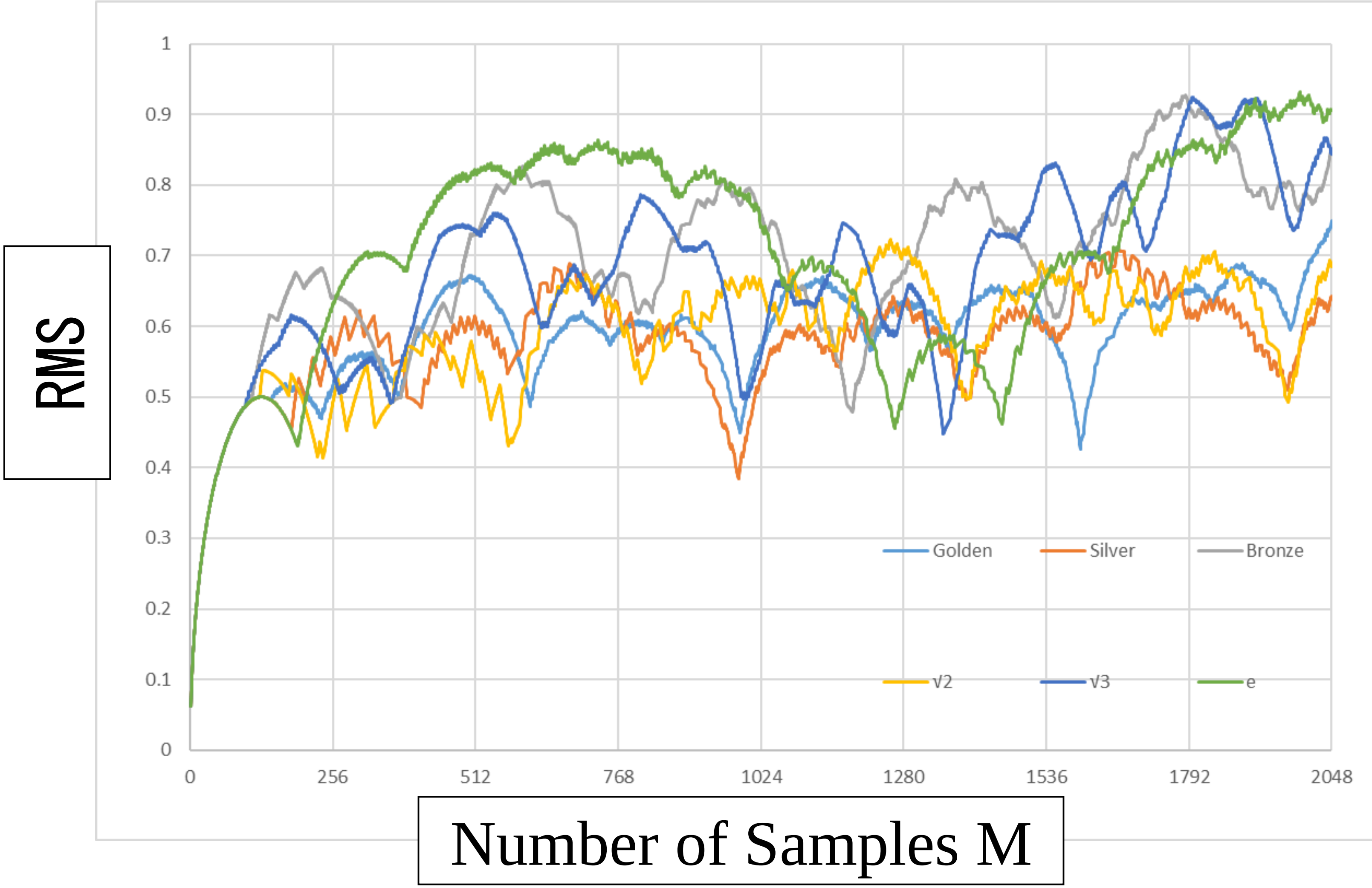




Total number of samples is *M* and
ADC resolution(the number of the histogram) is *N*.

ideal value $h_i(k) = \frac{M}{N}, k = 1,2,3,\ldots,N$ error $e(k) = \frac{N \cdot h(k)}{M} - 1$

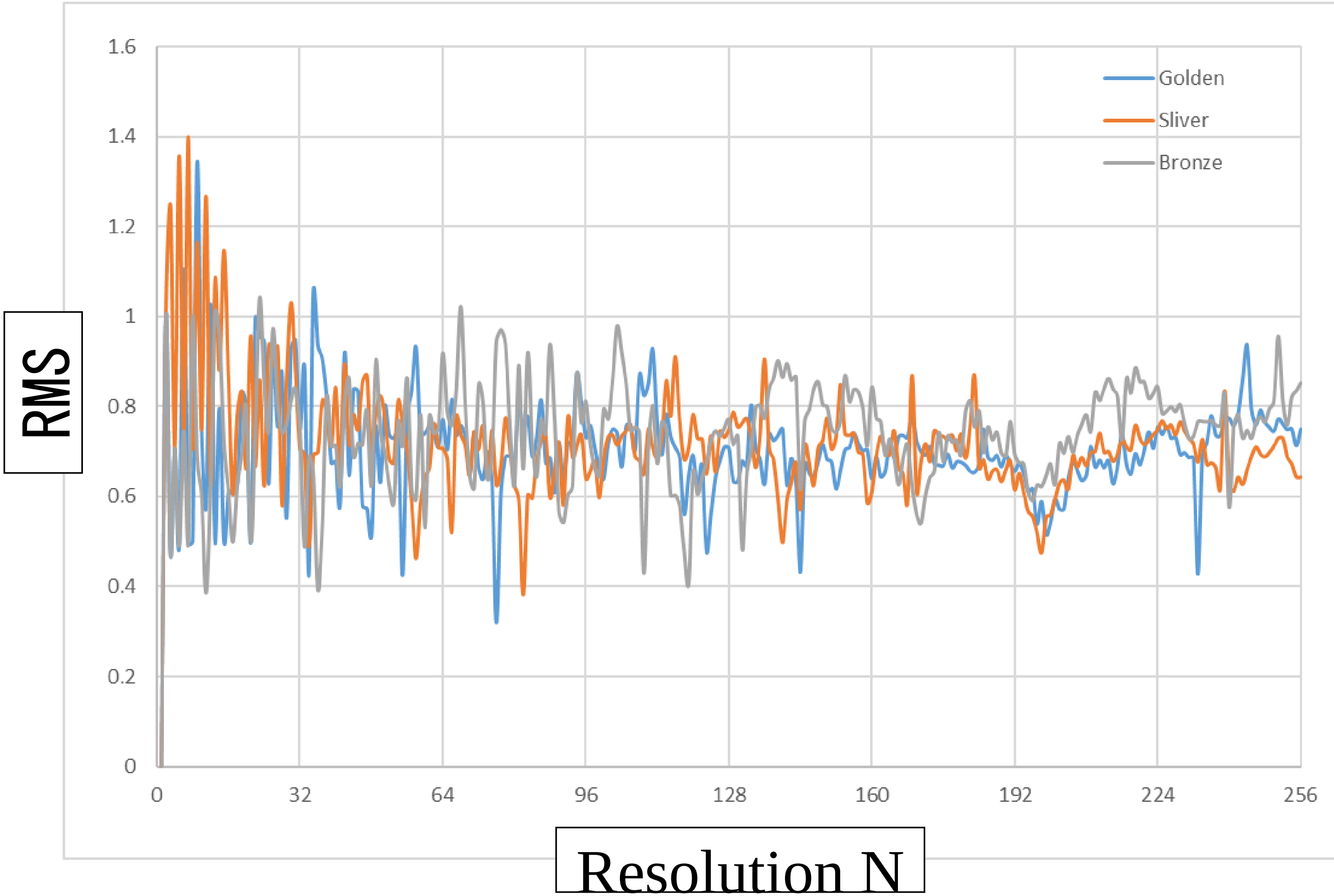
ADC Resolution 3Bit N = 8, Increase M



Root-Mean-Square of the errors between the actual and ideal histograms

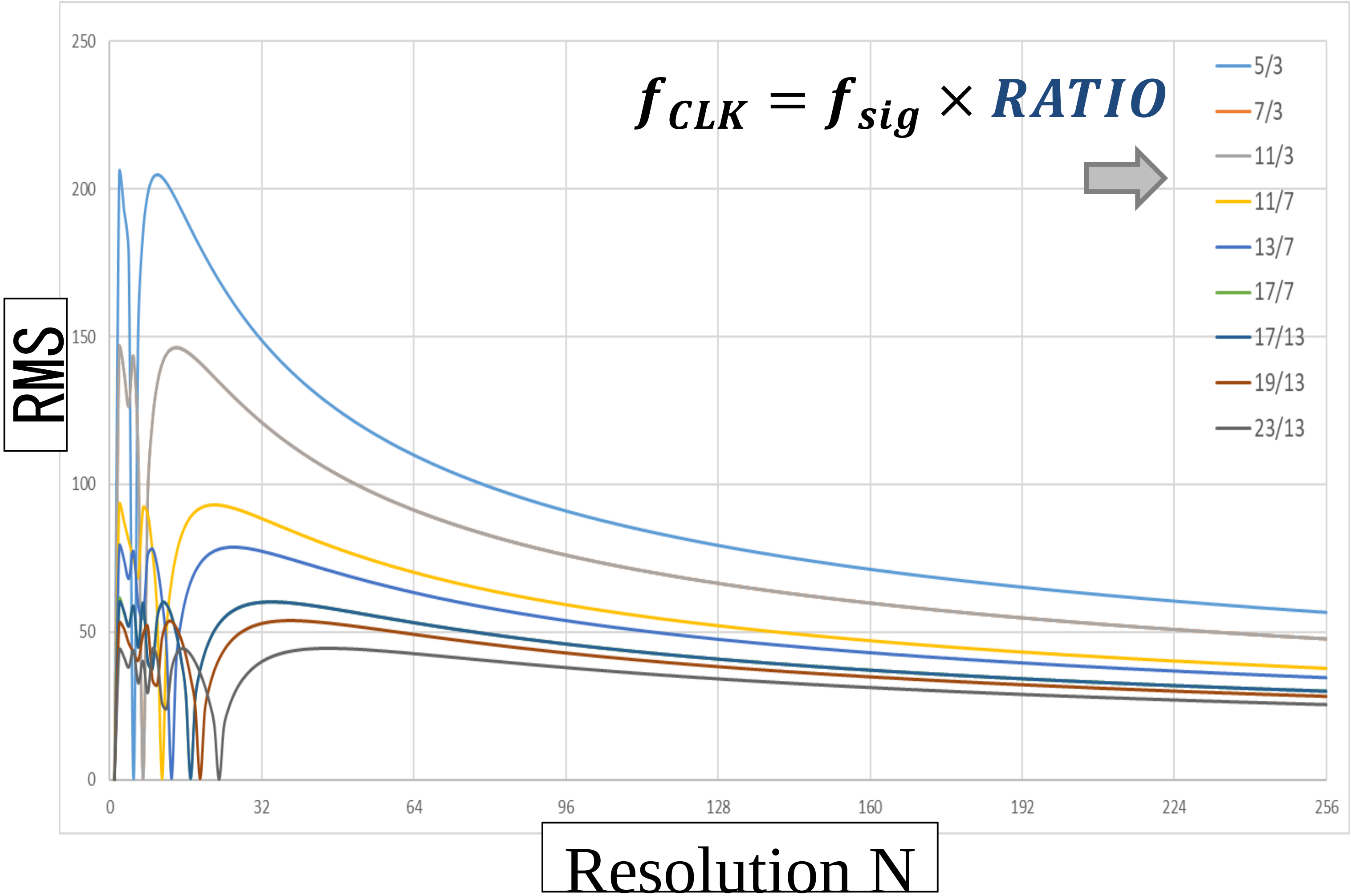
$$RMS = \sqrt{\frac{\sum (e(k))^2}{N}}$$

RMS between the actual and ideal



Total number of samples M = 2048, Increase resolution N. Compare RATIO

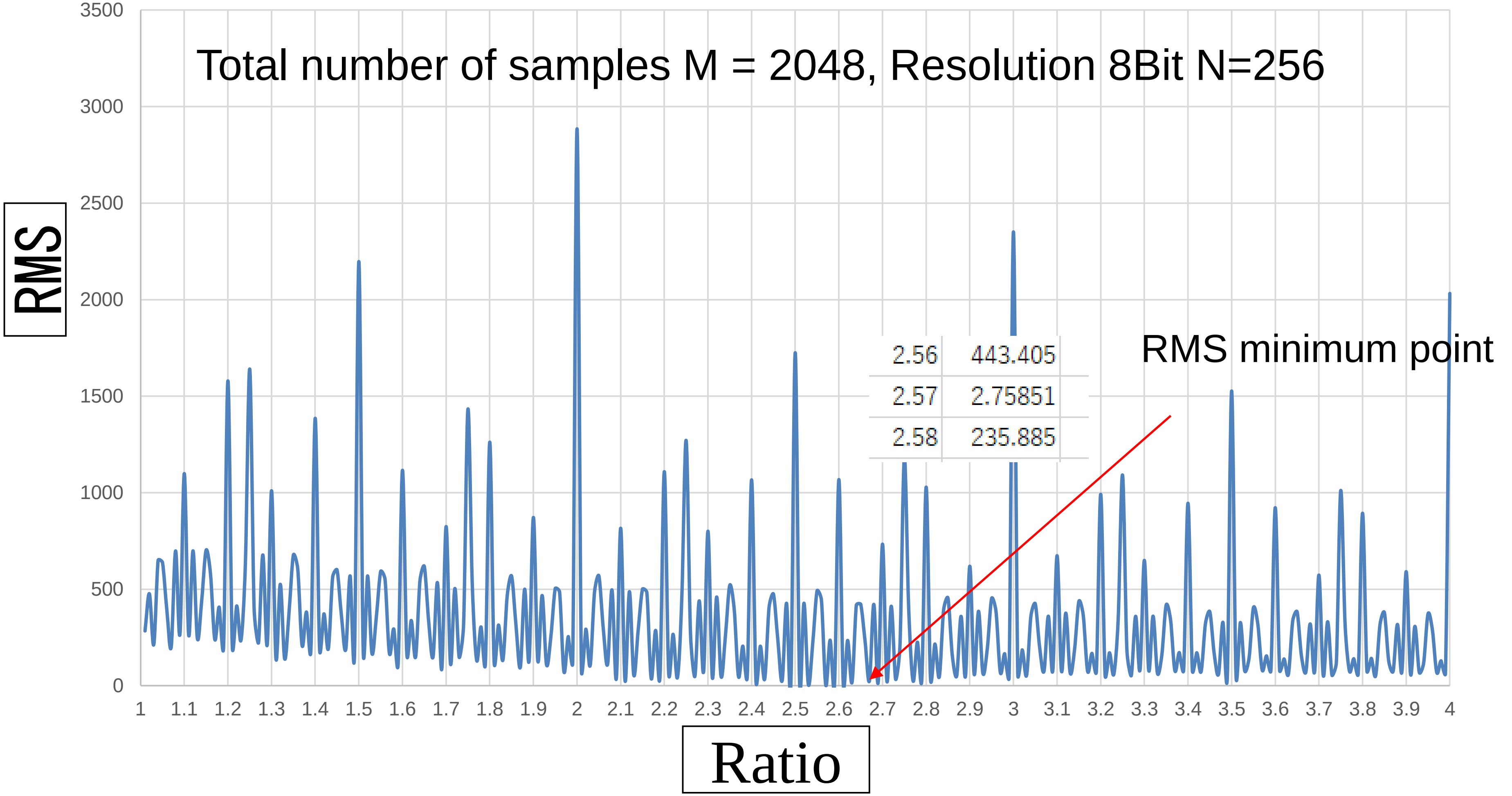
RMS of Prime Number Ratio



Total number of samples M = 2048, Increase resolution N. Compare RATIO

Most of the RMS results are not as good as Metallic ratio.

RMS results within a range(1~4)



Therefore, we calculated the RMS within
a certain range (1~4) to find a good ratio.

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Conclusion

Golden ratio sampling
Efficiency: Highest
Sampling frequency: low

Metallic ratio sampling
Efficiency: Good
Sampling frequency: High

Prime number ratio sampling
Efficiency:Not Good
Sampling frequency: High

next issue

- Find a ratio that is more efficient and has a smaller RMS like the golden ratio