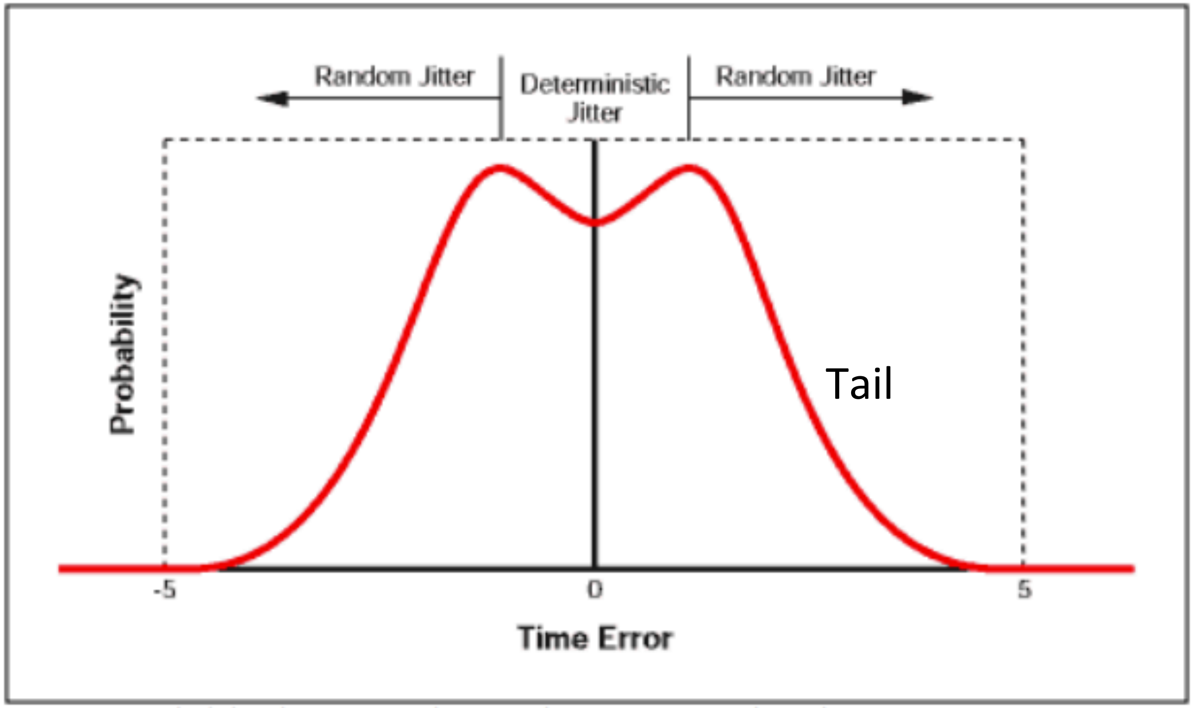
Introduction to JITTER

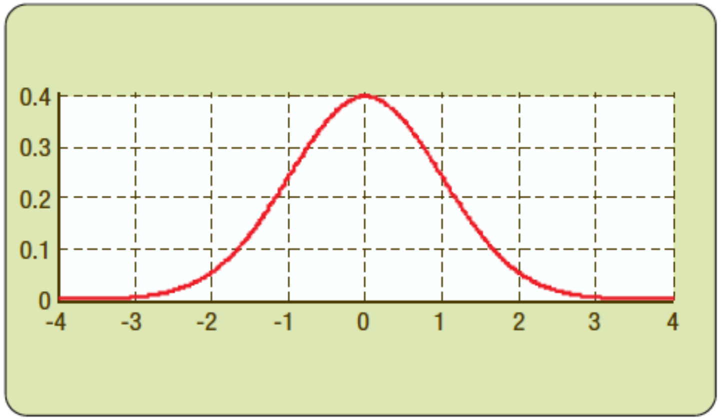
Timing Errors

- Long term variation from the ideal position
- Short term variation from the ideal position
- The SONET standard states that "Jitter is defined as the short-term variations of a digital signal's significant instants from their ideal positions in time
- Jitter Impact the BER
- Jitter types
  - Random
  - Deterministic
- Probability histogram showing deterministic and random components



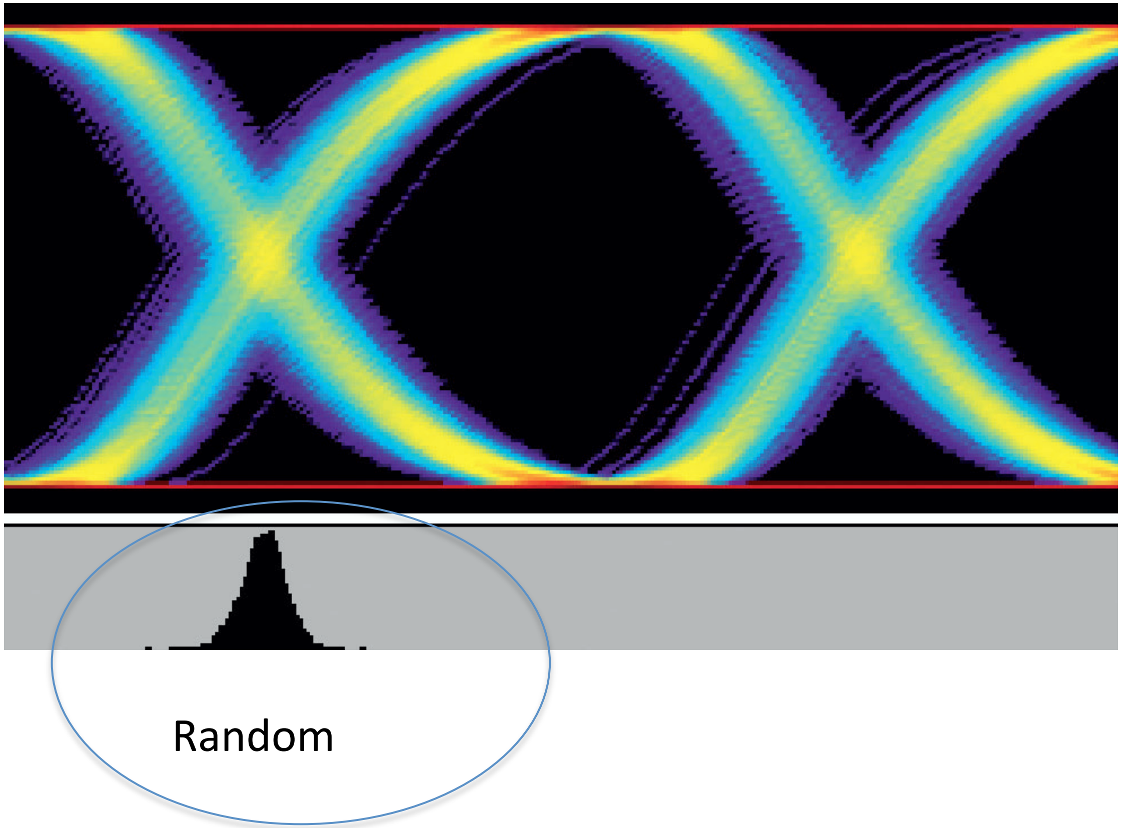
This is bimodal response

Random Jitter



- Random Jitter is probabilistic
  - Not bounded
  - Has a mean and standard deviation
  - It is called Gaussian (normal distribution)
  - Has no pattern and is not periodic
  - Since it is random variable we need N samples
- Mean: Mean Value: The arithmetic mean, or average, value of a clock period is the nominal period
- Standard Deviation: The standard deviation, represented by sigma (**σ**), is the average amount by which a measurement varies from its mean value
- RJ s measured based on Unit Interval
  - 1 UI = 1 Period (seconds)

Random Jitter



Random Total Jitter

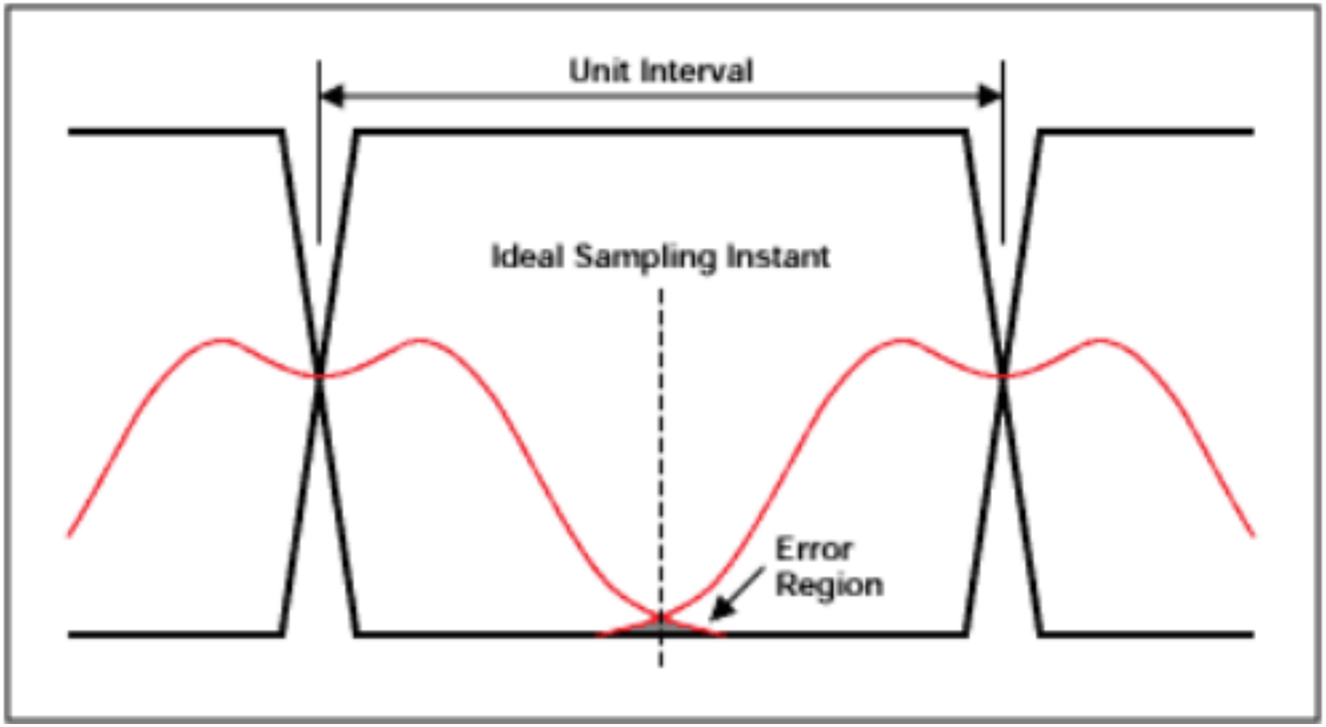
- Random Jitter that is not bounded and can be described by a Gaussian probability distribution
- Random jitter is characterized by its standard deviation (rms) value
- Gaussian distributions are symmetrical about a mean value.
- One standard deviation (1**σ**) is defined as the window which contains 68.26% of a population to one side of the mean.

Limit	Proportion of Population Within Limits
$\pm 1\sigma$	68.2689%
$\pm 2\sigma$	95.45%
$\pm 3\sigma$	99.73%
$\pm 4\sigma$	99.99367%
$\pm 5\sigma$	99.9999427%
$\pm 6\sigma$	$100-1.973 \times 10^{-7}$%
$\pm 7\sigma$	$100-2.5596 \times 10^{-10}$%
$\pm 8\sigma$	$100-1.24419 \times 10^{-13}$%
$\pm 9\sigma$	$100-2.25718 \times 10^{-17}$%
$\pm 10\sigma$	$100-1.53398 \times 10^{-21}$%

Each side of the population

Ideal Time Diagram and Jitter

- Jitter can result in error



Deterministic Jitter

- Predictable
- It is abounded
- Due to source imperfections
- Three sub-categories
  - Periodic Jitter (sinusoidal)
  - Data Dependent Jitter
  - Duty-Cycle Dependent

BER & Total Jitter

- To find the probability of a data error occurring, the sum of the probabilities of either data edge being in error must be multiplied by the probability of a transition actually occurring
- The probability of a transition actually occurring is represented by the average transition density and assumed to be equal to 50% for a typical data stream
- Total jitter is nxRJ + DJ
  - n is the number of standard deviations (σ) of random jitter that will produce a data error
  - In this expression RJ is in UI (rms) and DJ is in UI
  - Note that RJ and DJ are both expressed as peak UI – representing the worst case scenario

Limit	BER
$\pm 1\sigma$	0.16
$\pm 2\sigma$	2.28×10^{-2}
$\pm 3\sigma$	1.35×10^{-3}
$\pm 4\sigma$	0.32×10^{-4}
$\pm 5\sigma$	2.87×10^{-7}
$\pm 6\sigma$	0.98×10^{-9}
$\pm 7\sigma$	1.28×10^{-12}
$\pm 8\sigma$	0.62×10^{-15}
$\pm 9\sigma$	1.13×10^{-19}
$\pm 10\sigma$	0.77×10^{-23}

For a Gaussian distribution (RJ), for example, 1.28E-10% of samples lie outside a 7s limit to one side of the mean

BER & Total Jitter- Example

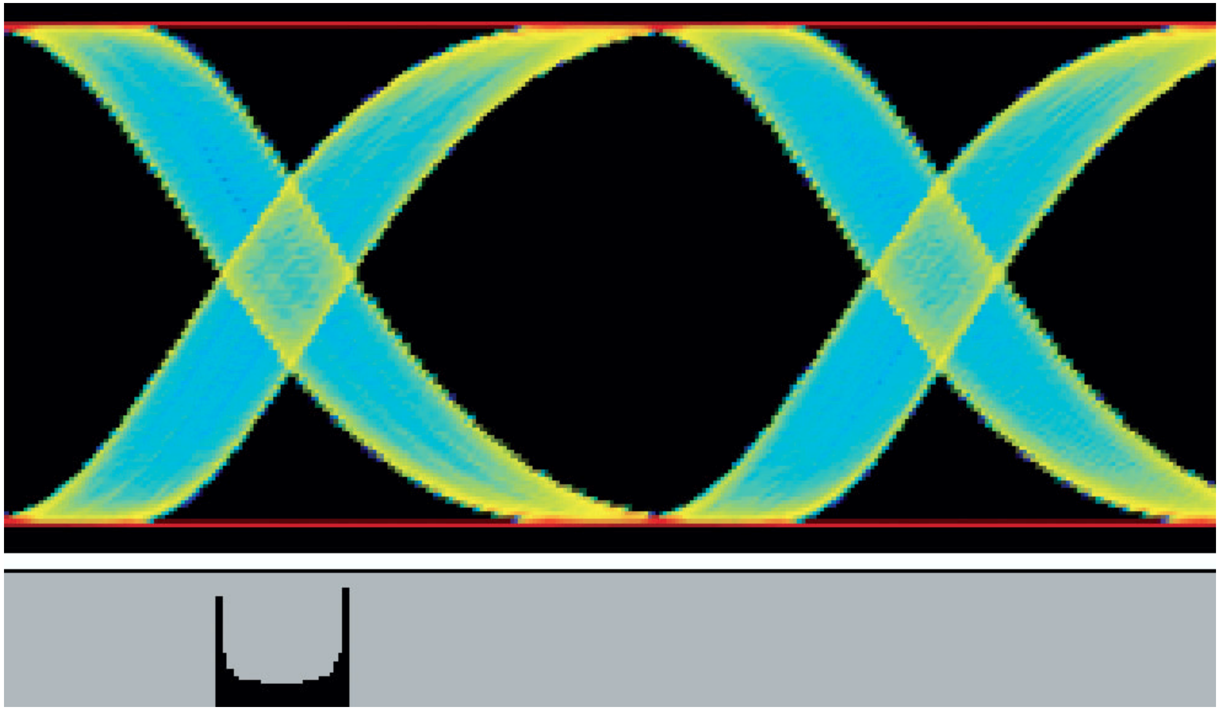
- Assume:
  - TJ = 0.5UI(pk), DJ = 0.15UI(pk) and RJ = 0.05UI(rms),
  - What is BER corresponding to the random jitter?

Limit	BER
±1σ	0.16
±2σ	2.28×10^{-2}
±3σ	1.35×10^{-3}
±4σ	0.32×10^{-4}
±5σ	2.87×10^{-7}
±6σ	0.98×10^{-9}
±7σ	1.28×10^{-12}
±8σ	0.62×10^{-15}
±9σ	1.13×10^{-19}
±10σ	0.77×10^{-23}

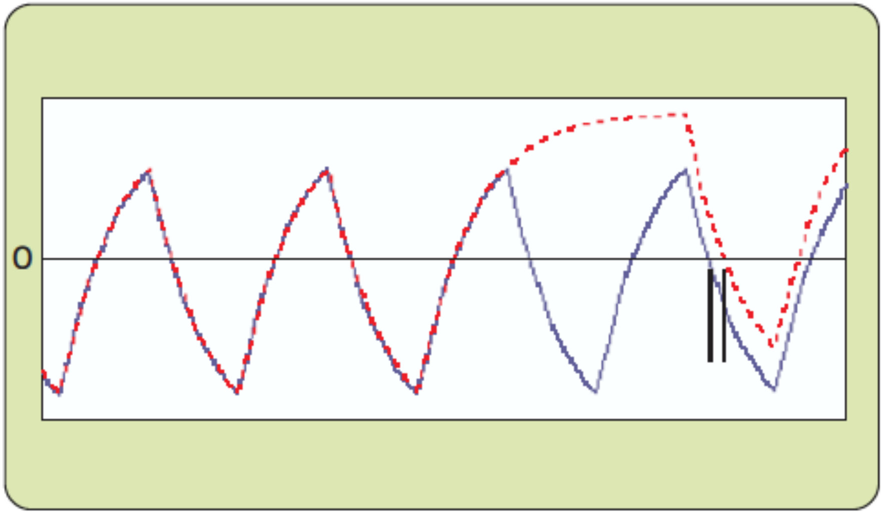
- Total jitter is TJ = nxRJ + DJ
- We find n = 7 ; corresponding to 7 Standard Deviation (SD)
  - This is the number of SD of random jitter that will produce a single data error
- For a Gaussian distribution (RJ), 1.28E-10% of samples lie outside a 7s limit to one side of the mean.
  - The total error rate (BER) is then given by samples which lie outside a +/-7s limits to both sides of the mean multiply average transition density (50% of typical data stream)
- BER = (1.28E-10% + 1.28E-10%) x 50% = 1.28 E-10%

Remember:
TJ is the total jitter that can be tolerated in order to support the intended BER!

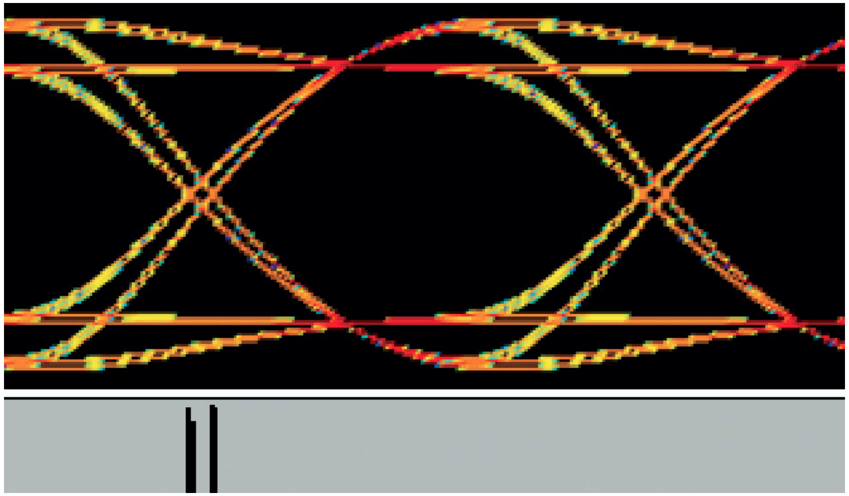
Periodic



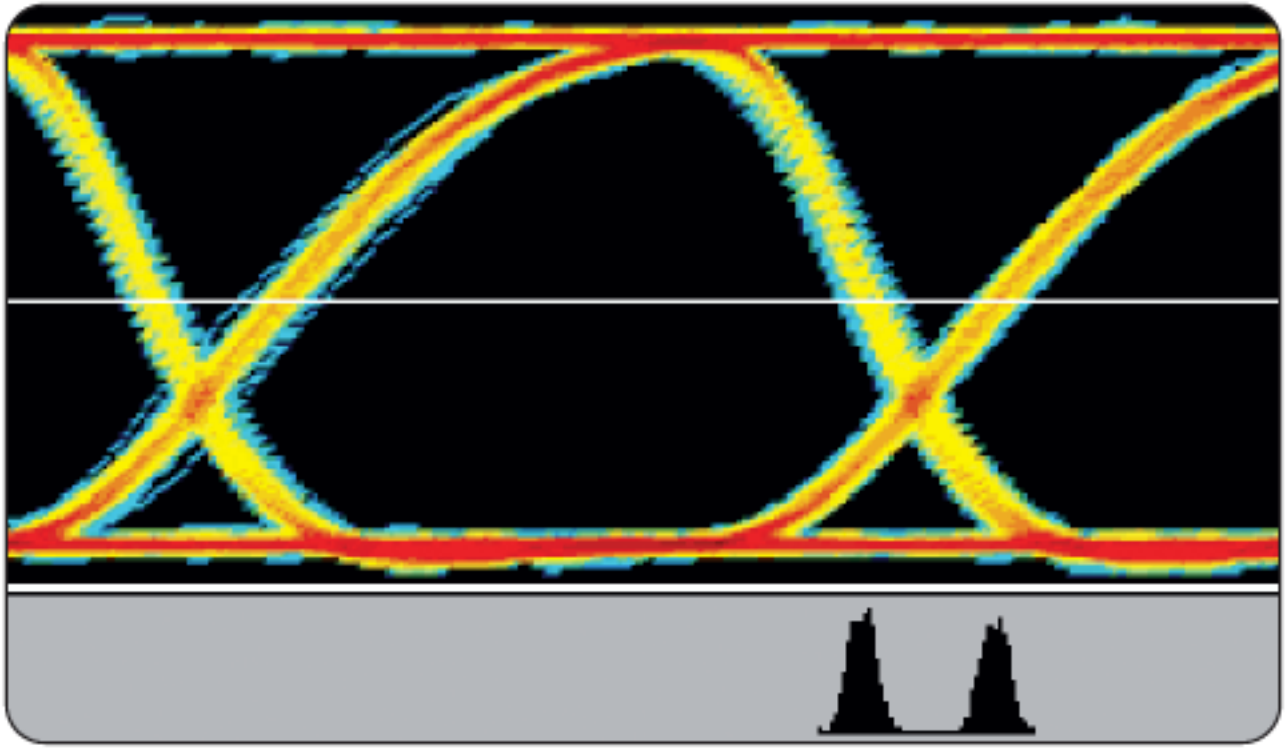
Data Dependent Jitter



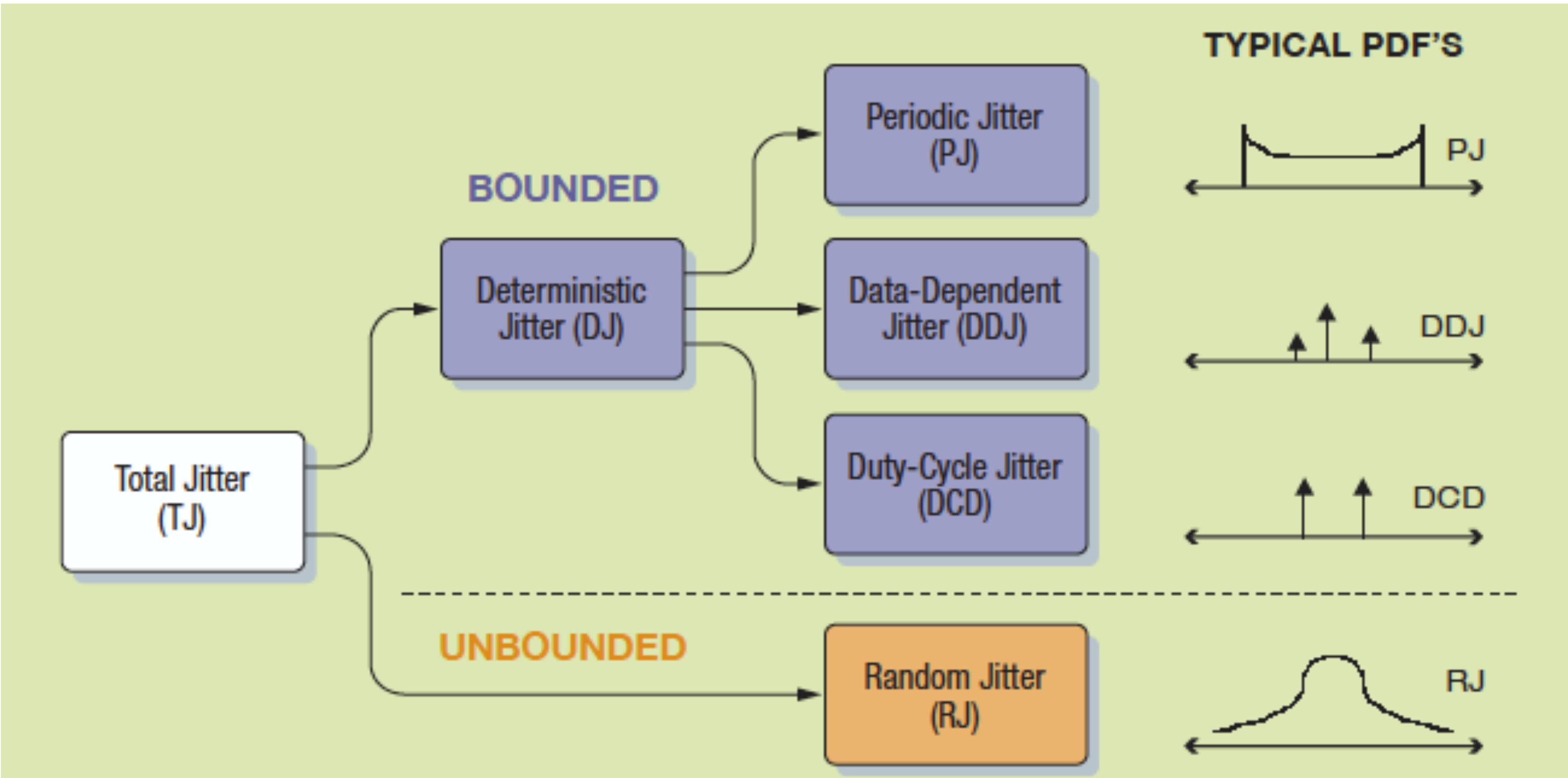
101010
Compared with 1010111
This is acting as LPF
→ ISI



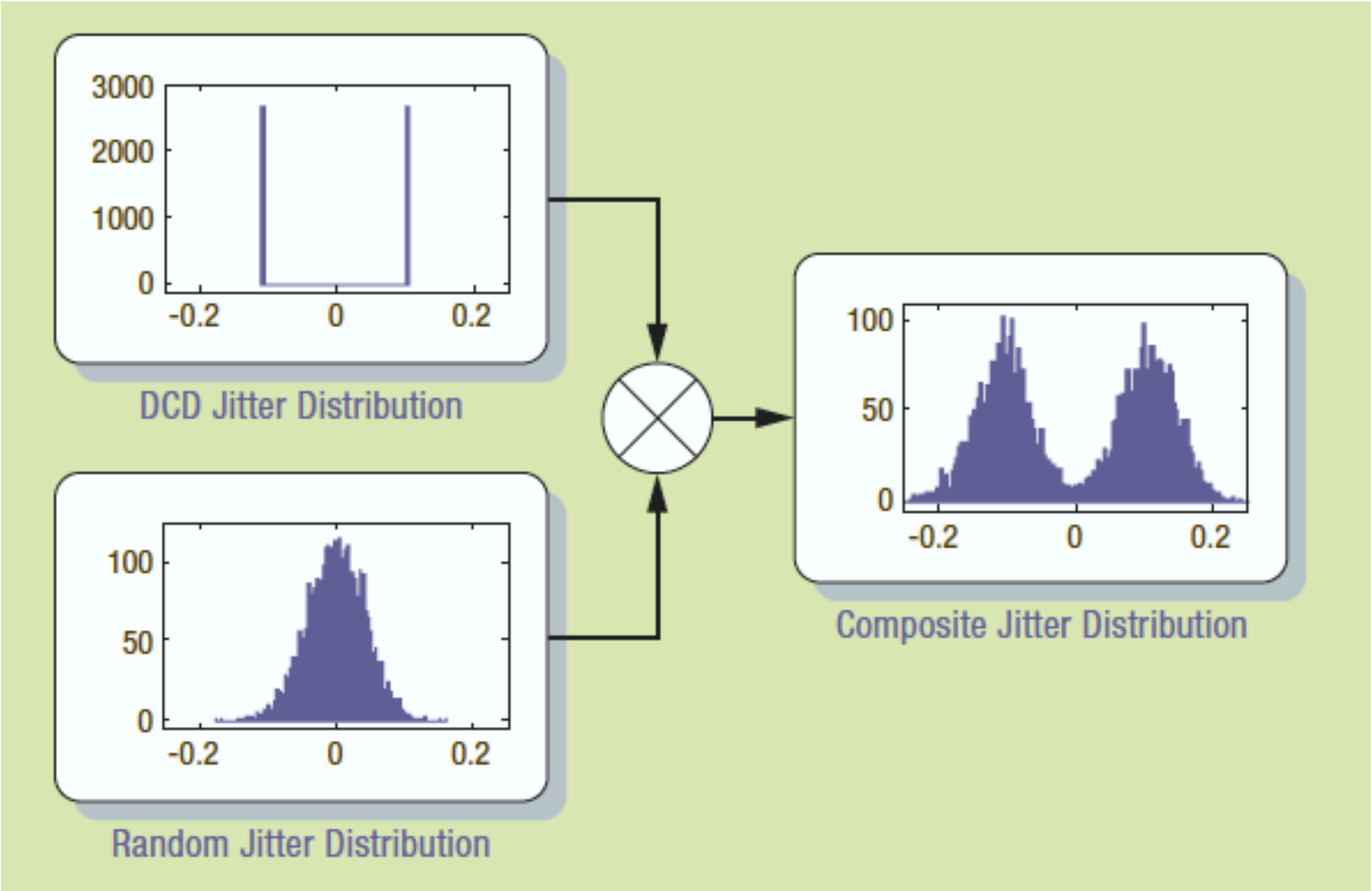
Duty –Cycle Dependent Jitter – Not symmetric



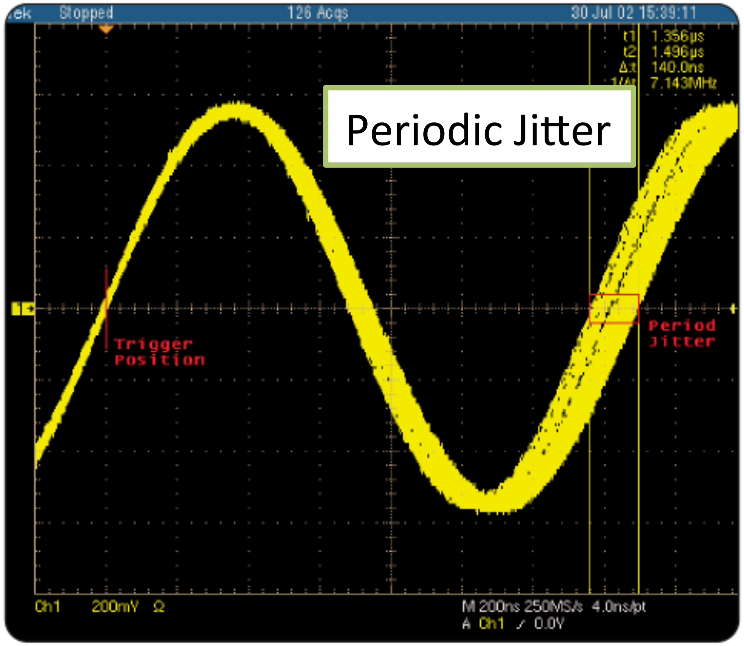
Jitter Separation

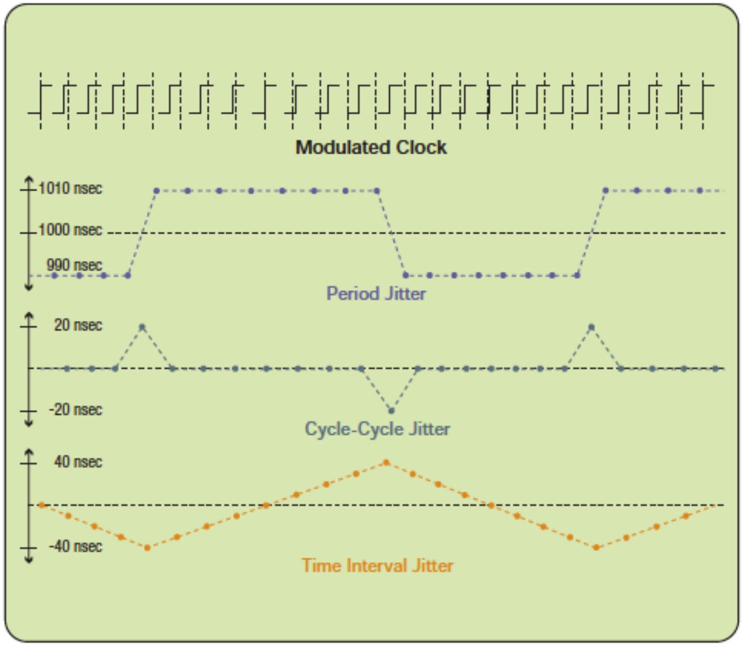


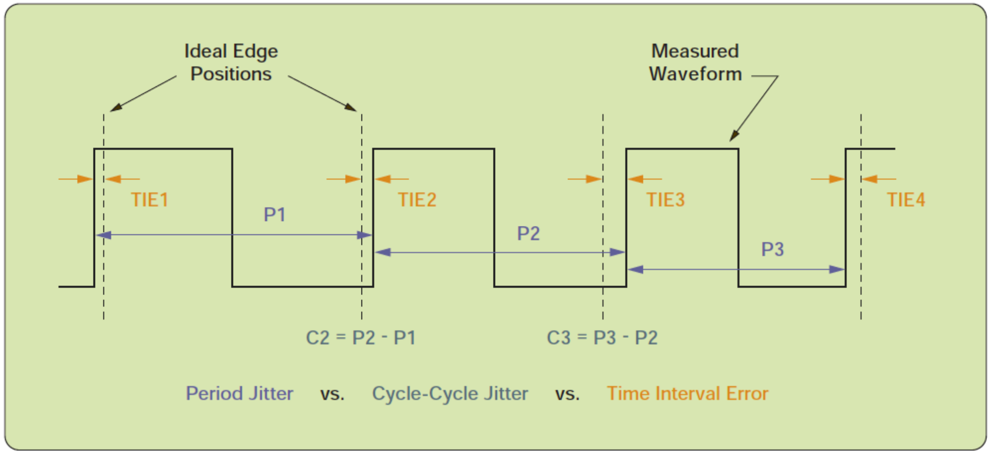
Total Jitter Example



Jitter Measurements

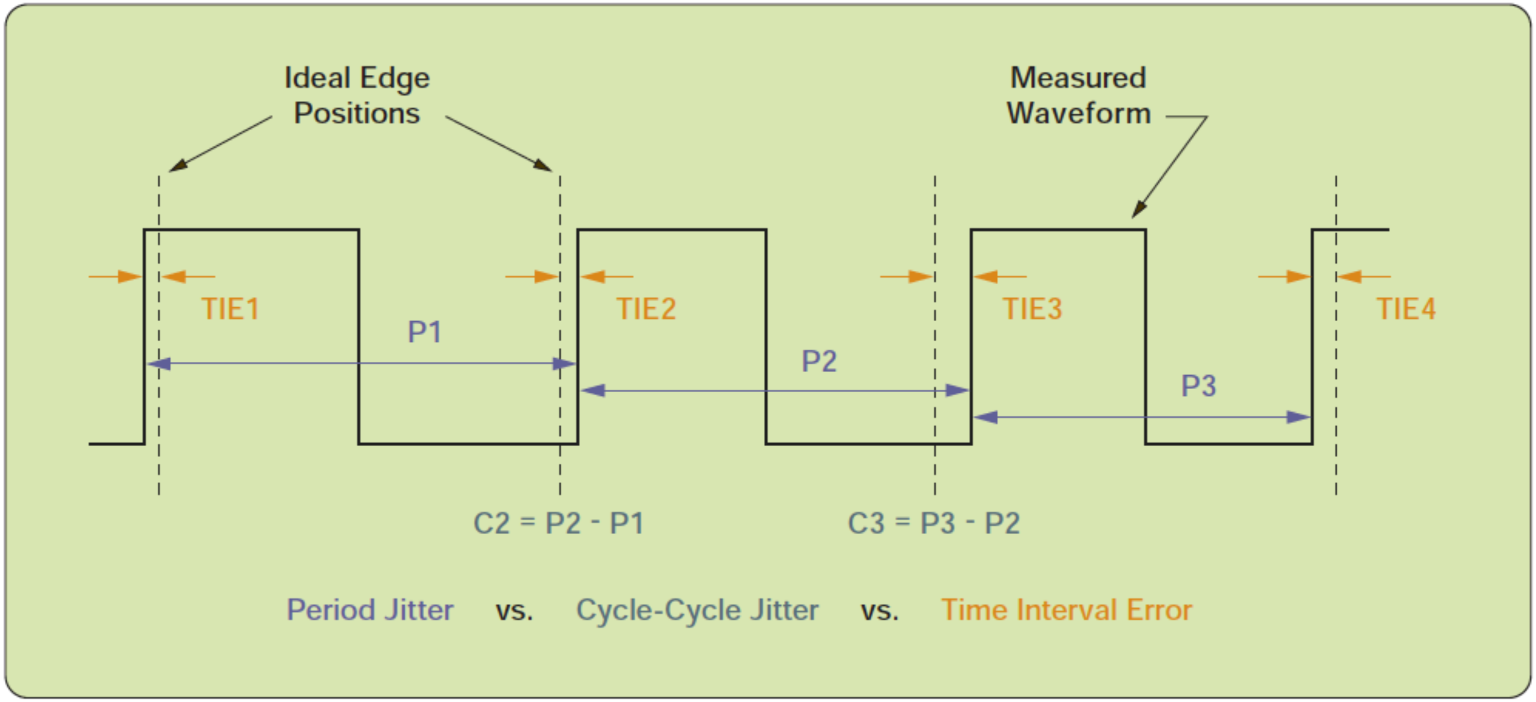






Deterministic Jitter Measurement Techniques

- Period Jitter (P1, P2, P3)
- Time Interval Error (Per Edge) – if more than 50% → eye is closed!
- Cycle-by-Cycle (C2, C3)



Example

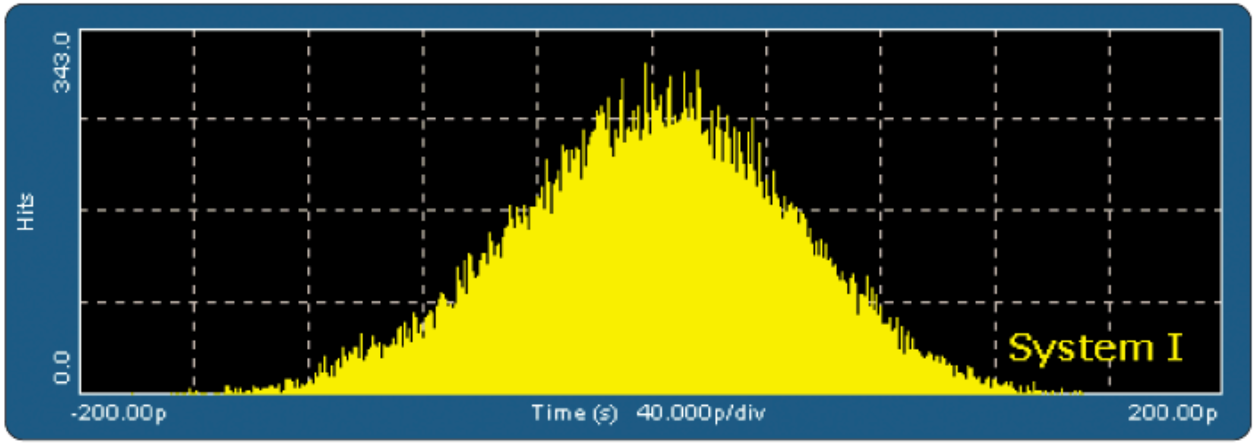
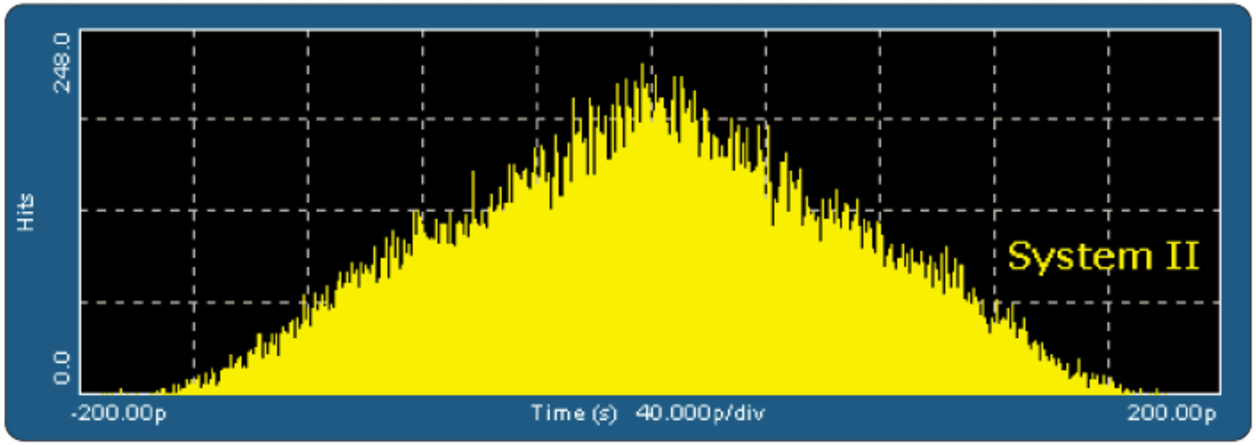


Figure 4.3b

R = 1062.5 Mbps
TIE = 430 psec (0.457 UI)
N (population samples) = 42K



It actually has periodic jitter components as well!
They are around 0.14 UI –
Cannot be obtained from the pic.