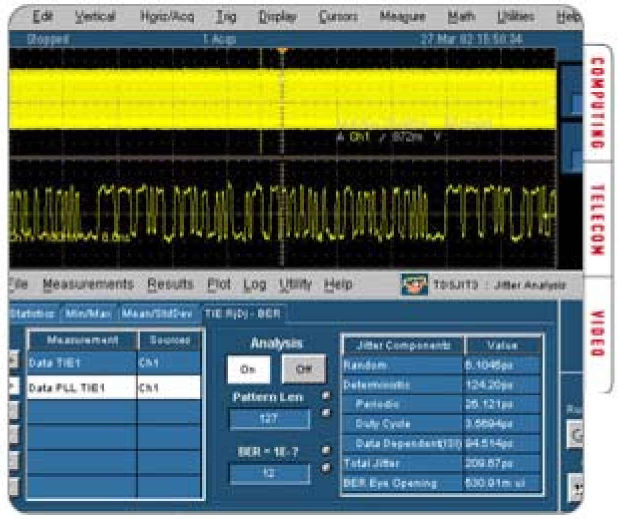

Jitter Analysis:

Algorithms

- Period Jitter
- Cycle-to-Cycle Jitter
- Frequency Jitter
- Time Interval Error
- General Measurements
- Clock-Data Measurements
- Calculating Statistics

Period Jitter

Period Jitter can be described as timing variation in the period of non-adjacent pulses. This measurement is useful for characterizing short and long-term clock stability.

Clock Period Measurement

The Clock Period measurement calculates the duration of a cycle as defined by a start and a stop edge. Edges are defined by slope, threshold, and hysteresis.

The application calculates this measurement using the following equation:

$$P_n^{Clock} = T_{n+1} - T_n$$

Where: P^{Clock} is the clock period.

T is the VRefMid crossing time in the Common Cycle Start Edge direction.

Data Period Measurement

The Data Period measurement calculates the duration of a cycle as defined by a start and a stop edge. Edges are defined by slope, threshold, and hysteresis.

The application calculates this measurement using the following equation:

$$P_n^{Data} = \left(T_n^{Data} - T_{n-1}^{Data}\right) / \left(C_n - C_{n-1}\right)$$

Where: P^{Data} is the data period.

T^{Data} is the VRefMid crossing time in either direction.

C_n is the calculated clock cycle location of T_n^{Data}.

Cycle to Cycle Jitter

Cycle to Cycle Jitter can be described as timing variation in the period of adjacent pulses. This measurement is useful for characterizing instantaneous and very short-term clock stability.

Clock Cycle-to-Cycle Measurement

The Clock Cycle–to–Cycle measurement calculates the difference in period measurements from one cycle to the next.

The application calculates this measurement using the following equation:

$$\Delta P_n = P_{n+1}^{Clock} - P_n^{Clock}$$

Where: ΔP is the difference between adjacent periods.

P^{Clock} is the period.

N-Cycle Measurement

The N–Cycle measurement calculates the difference in clock period measurements from cycles that are a defined number of cycles apart.

The application calculates this measurement using the following equation:

$$\Delta NP_n = \left(T_{n+2N}^{+} - T_{n-N}^{+}\right) - \left(T_{n+N}^{+} - T_n^{+}\right)$$

Where: ΔNP is the difference between adjacent N–cycle periods.

T^{+} is the VRefMid crossing time in the Common Cycle Start Edge direction.

Frequency Jitter

Frequency Jitter can be described as timing variation in the frequency of a signal. This measurement is useful for characterizing short and long-term clock stability.

Clock Frequency Measurement

The Clock Frequency measurement calculates the inverse of the clock period for each cycle.

The application calculates this measurement using the following equation:

$$F_n^{Clock} = 1 \big/ P_n^{Clock}$$

Where: F^{Clock} is the clock frequency.

P^{Clock} is the clock period.

Data Frequency Measurement

The Data Frequency measurement calculates the inverse of the data period for each cycle.

The application calculates this measurement using the following equation:

$$F_n^{Data} = 1 \big/ P_n^{Data}$$

Where: F^{Data} is the data frequency.

P^{Data} is the period.

Time Interval Error

Time Interval Error (TIE) can be described as timing variation in a signal relative to a reference signal. This measurement is useful for characterizing clock accuracy and short and long-term clock stability.

Clock TIE Measurement

The Clock TIE measurement calculates the difference in time between the designated edge on a sampled clock waveform to the designated edge on a calculated clock waveform with a constant frequency (zero jitter).

The application calculates this measurement using the following equation:

$$TIE_n^{Clock} = T_n^{Clock} - T_n'^{Clock}$$

Where: TIE^{Clock} is the clock time interval error.

T^{Clock} is the specified clock edge.

T'^{Clock} is the calculated ideal clock edge.

Clock PLL TIE Measurement

The Clock PLL TIE measurement calculates the difference in time between the designated edge on a sampled clock waveform to the designated edge on a clock waveform calculated by means of a PLL. Low frequency TIE components that are within the loop bandwidth of the PLL are tracked by the PLL and thereby removed.

The application calculates this measurement using the following equation:

$$TIE_n^{Clock} = T_n^{Clock} - T_n'^{Clock}$$

Where: TIE^{Clock} is the clock time interval error.

T^{Clock} is the specified clock edge.

T'^{Clock} is the recovered clock edge by means of a PLL.

Data PLL TIE Measurement

The Data PLL TIE measurement calculates the difference in time between the designated edge on a sampled data waveform to the designated edge on a data waveform calculated by means of a PLL. Low frequency TIE components that are within the loop bandwidth of the PLL are tracked by the PLL and thereby removed.

The application calculates this measurement using the following equation:

$$TIE_n^{Data} = T_n^{Data} - T_n'^{Data}$$

Where: TIE^{Data} is the data time interval error.

T^{Data} is the data edge, the VRefMid crossing time in either direction.

T'^{Data} is the recovered data edge by means of a PLL.

Data TIE Measurement With RjDj Analysis

The Data TIE measurement calculates the difference in time between the designated edge on a sampled data waveform to the designated edge on a calculated data waveform with a constant frequency (zero jitter).

The application calculates this measurement using the following equation:

$$TIE_n^{Data} = T_n^{Data} - T_n'^{Data}$$

Where: TIE^{Data} is the data time interval error.

T^{Data} is the data edge, the VRefMid crossing time in either direction.

T'^{Data} is the recovered data edge by means of a PLL.

General Measurements

Miscellaneous measurements are available to assist in characterizing signal integrity issues in new designs. Rise and fall time measurements are useful in determining whether a circuit has transient failures in meeting parametric specifications by measuring the rise and fall of each cycle in an acquired waveform. Similarly, duty cycle measurements can detect short or long half-period events.

Rise Time Measurement

The Rise Time measurement is the time difference between when the VRefHi reference level is crossed and the VRefLo reference level is crossed on the rising edge of the waveform. The Rise Time algorithm uses the VRef values as the reference voltage level. Each edge is defined by the slope, voltage reference level (threshold), and hysteresis.

The application calculates this measurement using the following equation:

$$T_n^{Rise} = T_n^{Hi+} - T_n^{Lo+}$$

Where: T^{Rise} is the rise time.

T^{Hi+} is the VRefHi crossing on the rising edge.

T^{Lo+} is the VRefLo crossing on the rising edge.

Fall Time Measurement

The Fall Time measurement is the time difference between when the VRefLo reference level is crossed and the VRefHi reference level is crossed on the falling edge of the waveform. The Fall Time algorithm uses the VRef values as the reference voltage level. Each edge is defined by the slope, voltage reference level (threshold), and hysteresis.

The application calculates this measurement using the following equation:

$$T_n^{Fall} = T_n^{Lo-} - T_n^{Hi-}$$

Where: T^{Fall} is the fall time.

T^{Lo-} is the VRefLo crossing on the falling edge.

T^{Hi-} is the VRefHi crossing on the falling edge.

Positive and Negative Width Measurements

The Positive Width and the Negative Width measurements are the difference in time (positive or negative) between the leading edge and trailing edge of a pulse. The trailing edge is the opposite polarity (direction) of the leading edge.

The application calculates these measurements using the following equations:

$$W_n^+ = T_n^- - T_n^+$$
$$W_n^- = T_n^+ - T_n^-$$

Where: W^+ is the positive pulse width.

W^- is the negative pulse width.

T^- is the VRefMid crossing on the falling edge.

T^+ is the VRefMid crossing on the rising edge.

High Time Measurement

The High Time Measurement is the amount of time that a waveform cycle is above the VRefHi voltage reference level.

The application calculates the measurement using the following equation:

$$T_n^{High} = T_n^{Hi-} - T_n^{Hi-}$$

Where: T^{High} is the high time.

T^{Hi-} is the VRefHi crossing on the falling edge.

T^{Hi+} is the VRefHi crossing on the rising edge.

Low Time Measurement

The Low Time measurement is the amount of time that a waveform cycle is below the VRefLo voltage reference level.

The application calculates this measurement using the following equation:

$$T_n^{Low} = T_n^{Lo+} - T_n^{Lo-}$$

Where: T^{Low} is the low time.

T^{Lo+} is the VRefLo crossing on the rising edge.

T^{Lo-} is the VRefLo crossing on the falling edge.

Clock Positive and Negative Duty Cycle Measurements

The Positive Duty Cycle and Negative Duty Cycle measurements calculate the ratio of the positive (or negative) portion of the cycle relative to the period.

The application calculates these measurements using the following equations:

$$D_n^+ = W_n^+ \Big/ P_n^{Clock}$$
$$D_n^- = W_n^- \Big/ P_n^{Clock}$$

The application calculates these measurements using the following equations:

Where: D^+ is the positive duty cycle.

D^- is the negative duty cycle.

W^+ is the positive pulse width.

W^- is the negative pulse width.

P^{Clock} is the period.

Clock Positive and Negative Cycle to Cycle Duty Measurements

The Positive Cycle–to–Cycle Duty and Negative Cycle–to–Cycle Duty measurements calculate the ratio of the positive (or negative) portion of the cycle relative to the period from one cycle to the next.

The application calculates these measurements using the following equations:

$$\Delta W_n^+ = W_n^+ - W_{n-1}^+$$

$$\Delta W_n^- = W_n^- - W_{n-1}^-$$

Where: ΔW^+ is the positive cycle–to–cycle duty.

ΔW^- is the negative cycle–to–cycle duty.

W^+ is the positive pulse width.

W^- is the negative pulse width.

Dual Waveform Measurements

About Dual Waveform Measurements

Edge conditions are defined for two waveforms. These algorithms use the VRef values as the reference voltage level. Each edge is defined by the slope, voltage reference level (threshold), and hysteresis.

Setup Time Measurement

The Setup Time measurement is the elapsed time between the designated edge of a data waveform and when the clock waveform crosses its own voltage reference level. The closest data edge to the clock edge that falls within the range limits is used.

The application calculates this measurement using the following equation:

$$T_n^{Setup} = T_i^{Main} - T_n^{2nd}$$

Where: T^{Setup} is the setup time.

T^{Main} is the Main input $\text{VRefMid}_{\text{Main}}$ crossing time in the specified direction.

T^{2nd} is the 2nd input (data) $\text{VRefMid}_{\text{2nd}}$ crossing time in the specified direction.

Hold Time Measurement

The Hold Time measurement is the elapsed time between when the clock waveform crosses its own voltage reference level and the designated edge of a data waveform. The closest data edge to the clock edge that falls within the range limits is used.

The application calculates this measurement using the following equation:

$$T_n^{Hold} = T_n^{2nd} - T_i^{Main}$$

Where: T^{Hold} is the hold time.

T^{Main} is the Main input $\text{VRefMid}_{\text{Main}}$ crossing time in the specified direction.

T^{2nd} is the 2nd input (data) $\text{VRefMid}_{\text{2nd}}$ crossing time in the specified direction.

Clock-Out Measurement

The Clock–to–Output Time measurement is the elapsed time between when the clock waveform crosses its own voltage reference level and the designated edge of a data waveform. The closest data edge to the clock edge that falls within the range limits is used.

The application calculates this measurement using the following equation:

$$T_n^{ClkOut} = T_n^{2nd} - T_i^{Main}$$

Where: T^{ClkOut} is the clock–to–output time.

T^{Main} is the Main input (clock) $\text{VRefMid}_{\text{Main}}$ crossing time in the specified direction.

T^{2nd} is the 2nd input (data) $\text{VRefMid}_{\text{2nd}}$ crossing time in the specified direction.

Skew Measurement

The Skew measurement calculates the difference in time between the designated edge on a principle waveform to the designated edge on another waveform. The closest data edge to the clock edge that falls within the range limits is used.

The application calculates this measurement using the following equation:

$$T_n^{Skew} = T_n^{Main} - T_n^{2nd}$$

Where: T^{Skew} is the timing skew.

T^{Main} is the Main input $VRefMid_{Main}$ crossing time in the specified direction.

T^{2nd} is the 2nd input $VRefMid_{2nd}$ crossing time in the specified direction.

Crossover Voltage Measurement

The Crossover Voltage measurement calculates the differential crossover voltage of two signals (the voltage where the two signals sum to zero).

The Skew measurement calculates the voltage level at the crossover voltage of a differential signal pair. If there is timing jitter on one of the pair of signal lines relative to the other, the crossover point will be modulated by the jitter. Crossover times are determined from the math waveform (main-cross) for a reference level of 0V.

The application calculates this measurement using the following equation:

$$V_n^{Crossover} = V_n^{Main}\left(T_n^{Crossover}\right)$$

Where: $V^{Crossover}$ is the crossing voltage.

V^{Main} is the voltage of the Main input.

$T^{Crossover}$ is the crossover time. It is the time when the two waveforms are equal in voltage.

This measurement detects each signal transition slope and each must be in the specified direction before it is included in the statistics.

Calculating Statistics

Maximum Value

The application calculates this statistic using the following equation:

$$Max(X) = Highest \cdot Value \cdot of \cdot X$$

Minimum Value

The application calculates this statistic using the following equation:

$$Min(X) = Lowest \cdot Value \cdot of \cdot X$$

Mean Value

The application calculates this statistic using the following equation:

$$Mean(X) = \overline{X} = \frac{1}{N}\sum_{n=1}^{N} X_n$$

Standard Deviation Value

It may seem odd that the equation for the estimate of the Standard Deviation contains a $1/N-1$ scaling factor. If you knew the true mean of X and used it in place of the estimated mean $\overline{X}$, then you would, in fact, scale by $1/N$. But, $\overline{X}$ is an estimate and is likely to be in error (or have bias), causing the estimate of the Standard Deviation to be too small to be scaled by $1/N$. This is the reason for the scaling shown in the equation.

(Refer to Chapter 9.2 in A. Papoulis, *Probability, Random Variables, and Stochastic Processes*, McGraw Hill, 1991.)

The application calculates this statistic using the following equation:

$$StdDev(X) = \sigma_X = \sqrt{\frac{1}{(N-1)}\sum_{n=1}^{N}\left(X_n - \overline{X}\right)^2}$$

Max Positive and Negative Difference Values

The application calculates the Max Positive Difference Value using the following equation:

$$Max(+X_{CC}) = Highest \cdot Positive \cdot Value \cdot of \cdot X_{CC}$$

Where $X_{CC} = X_n - X_{n-1}$

The application calculates Max Negative Difference Value using the following equation:

$$Max\left(-X_{CC}\right) = Lowest \cdot Negative \cdot Value \cdot of \cdot X_{CC}$$

Where $X_{CC} = X_n - X_{n-1}$

The Cycle-Cycle Value below is not displayed, but is used in calculations for Max Positive and Max Negative calculations.

$$X_{CC\,n} = X_n - X_{n-1}$$

Population Value

The application calculates this statistic using the following equation:

$$Population\,(X) = N$$

Contact Te k t r o n i x :
ASEAN / Australasia / Pakistan (65) 6356 3900

Austria +43 2236 8092 262

Belgium +32 (2) 715 89 70

Brazil & South America 55 (11) 3741-8360

Canada 1 (800) 661-5625

Central Europe & Greece +43 2236 8092 301

Denmark +45 44 850 700

Finland +358 (9) 4783 400

France & North Africa +33 (0) 1 69 86 80 34

Germany +49 (221) 94 77 400

Hong Kong (852) 2585-6688

India (91) 80-2275577

Italy +39 (02) 25086 1

Japan 81 (3) 3448-3010

Mexico, Central America & Caribbean 52 (55) 56666-333

The Netherlands +31 (0) 23 569 5555

Norway +47 22 07 07 00

People's Republic of China 86 (10) 6235 1230

Poland +48 (0) 22 521 53 40

Republic of Korea 82 (2) 528-5299

Russia, CIS& The Baltics +358 (9) 4783 400

South Africa +27 11 254 8360

Spain +34 (91) 372 6055

Sweden +46 8 477 6503/4

Taiwan 886 (2) 2722-9622

United Kingdom & Eire +44 (0) 1344 392400

USA 1 (800) 426-2200

USA (Export Sales) 1 (503) 627-1916

For other areas contact Te k t r o n i x ,I n c . at : 1 (503) 627-7111

01/03

Tektronix®
Enabling Innovation