Understanding Data Sheet Jitter Specifications for Cypress Timing Products

Introduction

This note describes how Cypress Semiconductor defines jitter for clock product data sheet specifications. There are several motivations for this. First, there is no accepted universal specification defining jitter for all applications. Therefore, each industry standard must define jitter for their own needs. However, these standards do not always share the same definitions. Also, some applications do not have associated standards governing them. Secondly, the growing importance of jitter in traditionally non-jitter sensitive applications has led to jitter terminology being used loosely in the industry, causing additional confusion.

The definitions set in this note only apply to those products specifically referring to this document in their respective data sheets. All other products contain the relevant jitter definitions within the body of their data sheet.

Unless otherwise noted, the jitter definitions provided below apply to periodic clock waveforms.

Types versus Components of Jitter

To clarify the discussion of jitter, we must first differentiate between “types” of jitter versus “components” of jitter. The type of jitter identifies the specific measurement that is made. The component of jitter identifies the statistical composition of jitter present. Examples of types of jitter include (but are not limited to) period jitter and cycle-to-cycle jitter. Components of jitter may be either random or deterministic. Thus, all *types* of jitter may be broken down into random and deterministic *components* of jitter.

However, since it is only possible to directly measure the total jitter (and not its random and deterministic components separately), Cypress only specifies total jitter on data sheets. While it is possible to apply a mathematical algorithm to decompose total jitter into its random and deterministic components, there is no industry agreed-upon methodology for the mechanics of this algorithm (i.e., covering such things as time scales, sampling domains, and the multitude of seemingly trivial minutia specific to the implementation of the algorithm, each having significant impact on the final decomposed values). For this reason, and since the jitter seen by any hardware system is simply the total jitter, our data sheet specifications do not apply mathematical algorithms to decompose jitter into random and deterministic components.

Input Jitter

All data sheet jitter specifications are based on measured characterization data (plus margin) and guaranteed by design. The measured data is not mathematically processed to subtract the input jitter. Jitter is a complex composition of statistical variables, whose correlation between each other and their interaction with the product’s bandwidth is very difficult to accurately model. Applying mathematical post-processing to the measured jitter compromises the integrity of the data by increasing the uncertainty of the result. Cypress’s strategy for measuring the most accurate intrinsic jitter therefore relies upon minimizing the input jitter. As a result, our jitter specifications include input jitter with intrinsic jitter, and are therefore conservative (to the extent that the input jitter influences the output jitter).

Data Sheet Format for Specifying Jitter

Specifications guaranteeing jitter appear on the data sheet as shown in *Figure 1*.

AC Specifications

Parameter	Description	Min	Max	Unit
$t_{jit(type)}$	Type of jitter, Peak-Peak		A	ps
$t_{jit(type)}$	Type of jitter, Peak		B	ps
$t_{jit(type)}$	Type of jitter, Peak	C	D	ps
$t_{jit(type)}$	Type of jitter, RMS		E	ps

Figure 1. This table illustrates the format for specifying jitter on the data sheet. The data sheet may have one or more of the rows shown in this table.

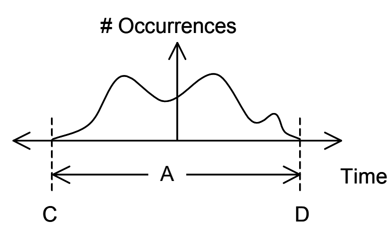

Figure 2. Generic Histogram (example) Illustrating the Relationship between Peak and Peak-Peak

The following terminology, as shown in *Figure 1* and *Figure 2*, is used in the next section for defining jitter specifications.

max peak-peak jitter = A = D – C

min peak jitter = C

max peak jitter = D, if min peak jitter (C) is specified on the data sheet, otherwise...

max peak jitter = B, which is the larger of |C| or D, if

min peak jitter (C) is not specified on the data sheet

RMS jitter = E

Definitions for Various Types of Jitter

This section defines the following types of jitter.

1. Period jitter
2. Half-period jitter
3. Cycle-to-cycle jitter
4. N-cycle jitter
5. N-cycle-to-cycle jitter
6. Half-period cycle-to-cycle jitter
7. Phase jitter
8. Dynamic-phase offset

1. Period Jitter

In accordance with JEDEC standard JESD65B, period jitter is defined as the deviation in cycle time of a signal with respect to the average period over a random sample of cycles. Mathematically, period jitter is defined as

$$t_{jit(per)} = t_{cyclen} - \frac{1}{f_o} \qquad \text{Eq. 1}$$

where f_o is the average (i.e., arithmetic mean, referred to as "mean" below) output frequency from the measured data and t_{cyclen} is any period measured on controlled edges.

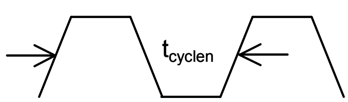

Figure 3. Waveform for Calculating Period Jitter

At least 1000 periods are measured (n $\geq$ 1000). The distribution of these periods is characterized by a mean of $1/f_o$, a standard deviation, and minimum (min) and maximum (max) periods. The data sheet may report any of the following parameters.

max peak-peak period jitter = max – min

min peak period jitter = min – mean

max peak period jitter = max – mean, if min peak period jitter is specified on the data sheet, otherwise...

max peak period jitter = the larger of (max-mean) or (mean-min), if min peak period jitter is not specified on the data sheet

RMS period jitter = standard deviation

2. Half-Period Jitter

In accordance with JEDEC standard JESD65B, half-period jitter is defined as the magnitude of the deviation in time duration between half-cycle threshold crossings of a single half-cycle over a random sample of half cycles. Mathematically, half-period jitter is defined as,

$$t_{jit(hper)} = t_{hpn} - \frac{0.5}{f_o} \qquad \text{Eq. 2}$$

where t_{hpn} is the n-th half-period measured, and f_o is the average frequency from the measured data.

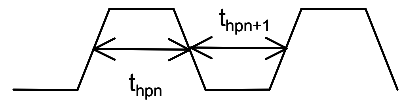

Figure 4. Half-period Measurement

At least 1000 half-periods are measured (n $\geq$ 1000). The distribution of these periods is characterized by a mean of $1/f_o$, a standard deviation, and minimum (min) and maximum (max) half-periods. The data sheet may report any of the following parameters.

max peak-peak half-period jitter = max – min

min peak half-period jitter = min – mean

max peak half-period jitter = max – mean, if min peak half-period jitter is specified on the data sheet, otherwise...

max peak half-period jitter = the larger of (max-mean) or (mean-min), if min peak half-period jitter is not specified on the data sheet

RMS half-period jitter = standard deviation

3. Cycle-to-Cycle (C2C) Jitter

In accordance with JEDEC standard JESD65B, C2C jitter is defined as the variation in cycle time of a signal between adjacent cycles, over a random sample of adjacent cycle pairs. Mathematically, C2C jitter is defined as,

$$t_{jit(c2c)} = |t_{cyclen+1} - t_{cyclen}| \qquad \text{Eq. 3}$$

where t_{cyclen} and $t_{cyclen+1}$ are any two adjacent periods measured on controlled edges.

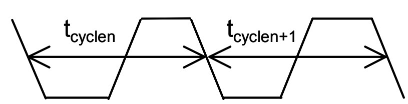

Figure 5. Waveform for C2C Jitter calculation

At least 1000 C2C jitter measurements are made (n $\geq$ 1000). The distribution of C2C jitter is one-sided, as dictated by the absolute value in the definition. This distribution is characterized by its root-mean-square value, and a maximum C2C jitter. The data sheet may report any of the following parameters.

peak C2C jitter = maximum measured value of $t_{jit(c2c)}$

RMS C2C jitter = root-mean-square of the distribution for $t_{jit(c2c)}$

Other companies might define C2C jitter without an absolute value sign. *Figure 6(a)* shows how the distribution changes for this alternate definition (Curve B). However, our definition's RMS value (Curve A) is mathematically equal to Curve B's standard deviation. This is because the equation for standard deviation simplifies to the equation for RMS when the mean of the distribution (the distribution that is used to calculate the standard deviation) is zero. Therefore, RMS_A and the standard deviation from Curve B (σ_B) are equivalent measures of C2C jitter, as shown in *Figure 6(b)*. Note, however, that the RMS value of Curve A does not equal its standard deviation (*Figure 6(c)*), since the mean of Curve A is not zero. Although a Gaussian curve is drawn for simplicity in *Figure 6*, the curve in reality may or may not be Gaussian.

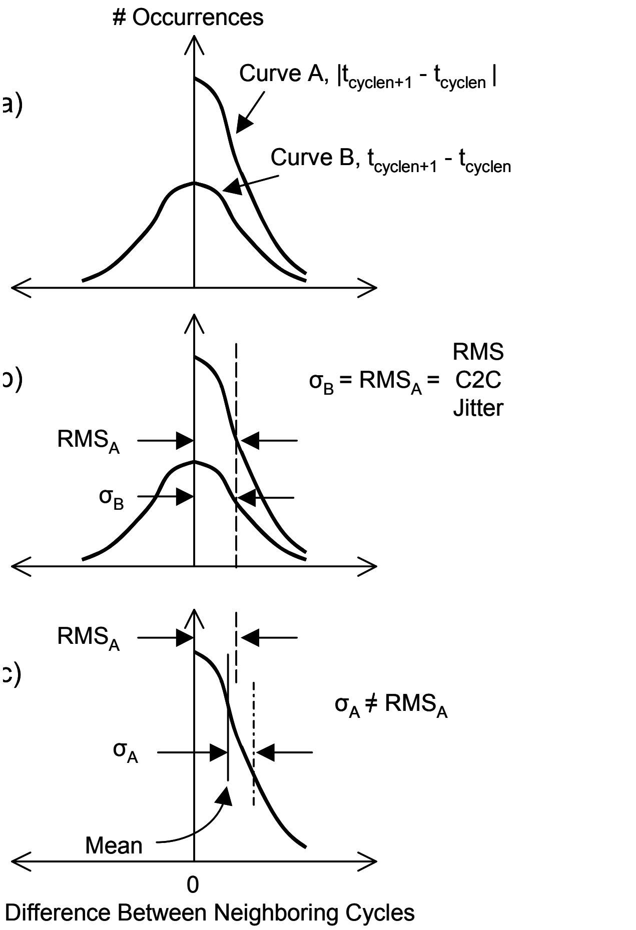

Figure 6. Illustration of the relationship between standard deviation and RMS values for our definition of C2C jitter (Curve A) versus an alternate definition (Curve B)

4. N-Cycle Jitter

N-cycle jitter measures the variation between the output clock's first and N-th rising edges. The exact value of N depends on the application. For PC motherboard and graphics applications, the N-th cycle usually occurs around 10–20 microseconds. Other applications may differ.

Mathematically, N-cycle jitter is defined as,

$$t_{jit(N)} = t_N - t_o \qquad \text{Eq. 4}$$

where t_N and t_o are the instantaneous and mean time differences, respectively, between the first and N-th rising edges.

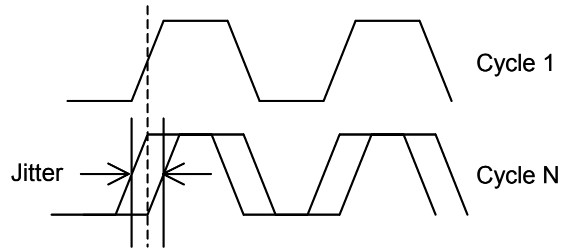

Figure 7. Illustration of N-cycle Jitter

At least 1000 N-cycle jitter measurements are made. The distribution of these measurements is characterized by a standard deviation, a most negative time deviation (nmax), and a most positive time deviation (pmax). The data sheet may report any of the following parameters.

max peak-peak N-cycle jitter = pmax – nmax

min N-cycle jitter = nmax

max peak N-cycle jitter = pmax, if min peak N-cycle jitter is specified on the data sheet, otherwise...

max peak N-cycle jitter = the larger of |nmax| or pmax, if min peak N-cycle jitter is not specified on the data sheet

RMS N-cycle jitter = standard deviation

5. N-Cycle-to-Cycle (N-C2C) Jitter

N-C2C jitter is defined as the variation in time of a signal between adjacent intervals, where each interval is N cycles (i.e., periods) long, over a random sample of adjacent interval pairs. Mathematically, N-C2C jitter is defined as,

$$t_{jit(Nc2c)} = t_{Ncyclen+1} - t_{Ncyclen} \qquad \text{Eq. 5}$$

where $t_{Ncyclen}$ and $t_{Ncyclen+1}$ are any two adjacent intervals of time, each equal to N cycles long, measured on controlled edges.

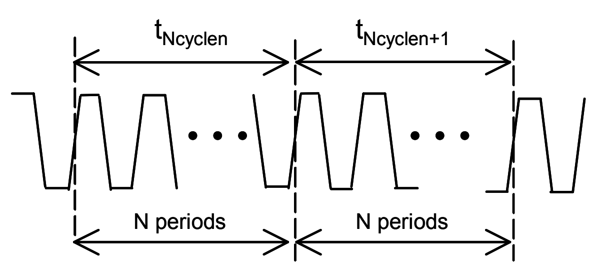

Figure 8. Waveform for N-C2C Jitter calculation

At least 1000 N-C2C jitter measurements are made ($n \geq 1001$). The distribution of N-C2C jitter is characterized by its standard deviation, a most negative time deviation (nmax), and a most positive time deviation (pmax). The data sheet may report any of the following parameters.

max peak-peak N-C2C jitter = pmax – nmax

min N-C2C jitter = nmax

max peak N-C2C jitter = pmax, if min peak N-C2C jitter is specified on the data sheet, otherwise...

max peak N-C2C jitter = the larger of |nmax| or pmax, if

min peak N-C2C jitter is not specified on the data sheet

RMS N-C2C jitter = standard deviation

6. Half-Period Cycle-to-Cycle (HP-C2C) Jitter

Half-period cycle-to-cycle jitter is defined as the variation in time of a signal between matching half-periods between adjacent periods over a random sample of adjacent matching half-period pairs. Mathematically, HP-C2C jitter is defined as,

$$t_{jit(hperc2c)} = t_{hpn+1(-)} - t_{hpn(-)} \quad \text{Eq. 6}$$

and

$$t_{jit(hperc2c)} = t_{hpn+1(+)} - t_{hpn(+)}$$

where $t_{hpn+1(-)}$ and $t_{hpn(-)}$ are any two adjacent periods' negative-polarity half-periods, and $t_{hpn+1(+)}$ and $t_{hpn(+)}$ are any two adjacent periods' positive-polarity half-periods, measured on controlled edges.

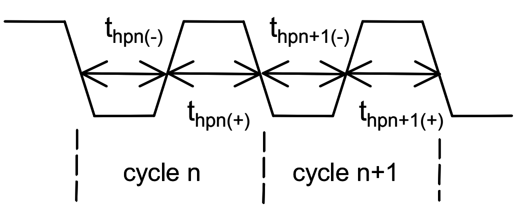

Figure 9. Waveform for HP-C2C Jitter Calculation

At least 1000 HP-C2C jitter measurements are made ($n > 1001$). The distribution of HP-C2C jitter is characterized by its standard deviation, a most negative time deviation (nmax), and a most positive time deviation (pmax). The data sheet may report any of the following parameters.

max peak-peak HP-C2C jitter = pmax – nmax

min HP-C2C jitter = nmax

max peak HP-C2C jitter = pmax, if min peak HP-C2C jitter is specified on the data sheet, otherwise...

max peak HP-C2C jitter = the larger of |nmax| or pmax, if min peak HP-C2C jitter is not specified on the data sheet

RMS HP-C2C jitter = standard deviation

7. Phase Jitter

Phase jitter is calculated by filtering the measured phase-noise data with an industry-standard defined filter, and integrating the result across offset frequency to derive an RMS phase-jitter value.

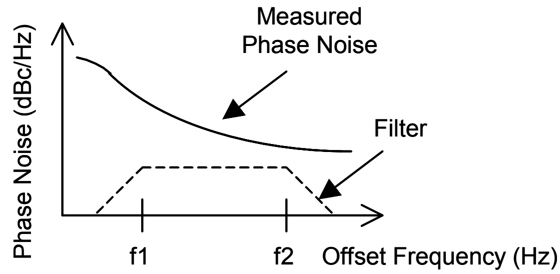

Figure 10. Phase Jitter is calculated by applying an industry-defined filter to a phase-noise graph and integrating across frequency to calculate an RMS number.

The data sheet reports phase jitter in units of time, at a specific carrier frequency. The values of f1 and f2 (and roll-off characteristics, if appropriate) as dictated by the end-market specification are also provided in the data sheet. It is not possible to directly measure peak values from a phase-noise graph.

8. Dynamic Phase Offset

Dynamic phase offset (DPO) is a type of PLL jitter that defines the variation in time difference between the input reference clock and the PLL feedback input signal with respect to the mean for a random sample of cycles, when the PLL is locked and the input reference frequency is stable. DPO is the ac counterpart to static-phase offset.

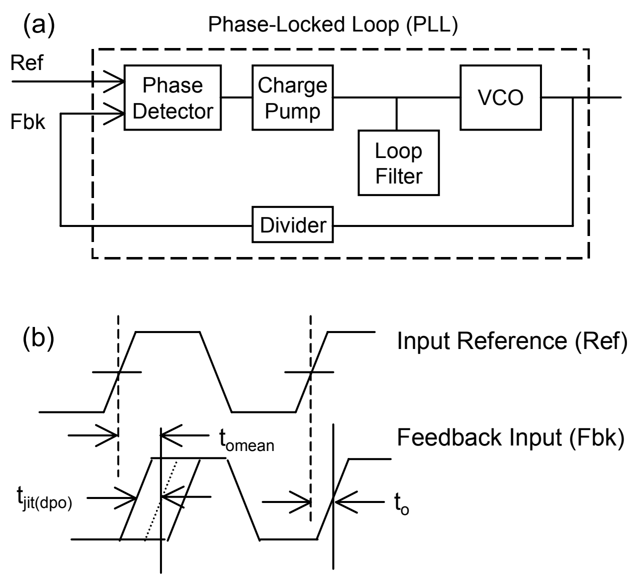

Figure 11. (a) Application diagram, and (b) waveforms used in the calculation of dynamic phase offset

Mathematically, DPO is defined as,

$$t_{jit(dpo)} = t_o - t_{omean} \quad \text{Eq. 7}$$

where t_o is the time difference between reference and feedback inputs, and t_{omean} is its average value.

At least 1000 DPO measurements are taken. The distribution of these measurements is characterized by a standard deviation, a most negative phase offset (nmax) and a most positive phase offset (pmax). The data sheet may report any of the following parameters.

max peak-peak DPO = pmax – nmax

min peak DPO = nmax

max peak DPO = pmax, if min peak DPO is specified on on the data sheet, otherwise...

max peak DPO = the larger of |nmax| or pmax, if min peak DPO is not specified on the data sheet

RMS DPO = standard deviation

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