Jitter and Phase Noise Relationships

Jitter represents the timing error of digital signals, while phase noise describes the spectral content of noise in analog systems. There are some key relationships between these two factors, as described below. While jitter and phase noise are related, they are not precisely equivalent, i.e., there are no closed-form mathematical expressions that describe the conversion between them. However, good approximations are possible, which is how they are usually handled in analytic environments such as design software.

Figure 1 shows graphical definitions of jitter and phase noise. Jitter is the time deviation from period-to-period of the clock waveform. RMS jitter is the most common specification, although there are uses for peak-to-peak jitter values. Also, jitter is most commonly defined as cycle-to-cycle; as the RMS value of the deviation from the average period. In some cases, jitter may also be analyzed as the deviation from the ideal period.

Phase noise is specified as a plot of amplitude versus offset from the center frequency. A plot is required because phase noise is not a predictable function. However, there are three general regions where approximations can be made. The first is close to f_c where $1/f$ noise is present. Bipolar transistor oscillators have a $1/f$ "corner frequency" (where $1/f$ noise falls below other noise contributors) around 1 kHz, while MOSFETs (e.g., CMOS ICs) may have a corner frequency as high as 1 MHz. The next region, which is the major contributor to total noise, has an amplitude rolloff of approximately $1/(f_{offset})^3$. The final region, which is farther from f_c and lower in amplitude, has a rolloff of approximately $1/(f_{offset})^2$.

A reasonably accurate correlation of phase noise and jitter can be achieved with a piecewise linear approximation using these three regions of phase noise (Fig. 2). The $1/(f_{offset})^3$ region is dominant in most oscillators, and may be used as a first-order approximation as shown in the following equations [2]:

$$L(f) = \frac{\sigma^2 f_c^3}{f^2}$$

$$\sigma^2 = \frac{f^2 L(f)}{f_c^3}$$

where $f = f_{offset}$, $L(f)$ is the phase noise at f_{offset}, and σ is the jitter. Note that other references may use different notations or derive relationships differently. For more in-depth mathematical explanations, readers are directed to the References and other resources.

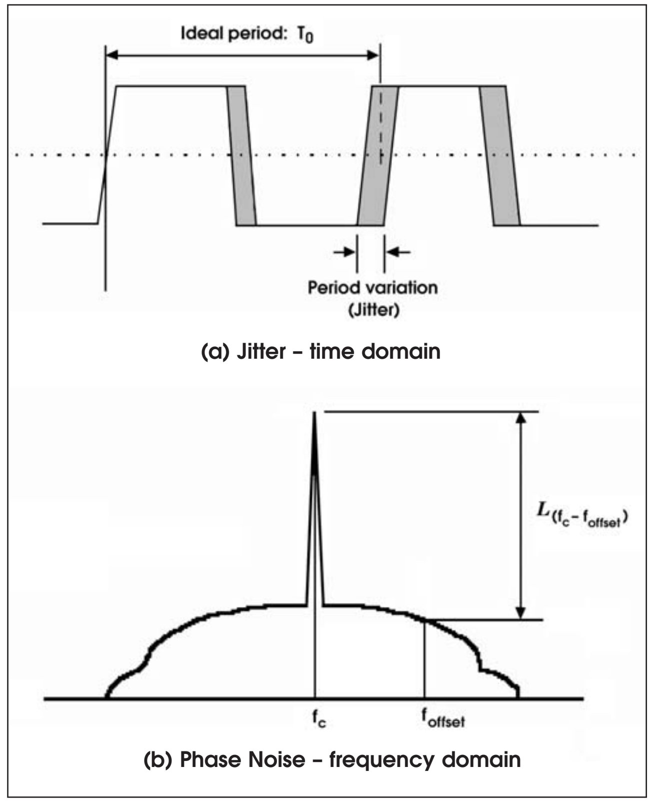

Figure 1 · Diagrams defining jitter (a) and phase noise (b).

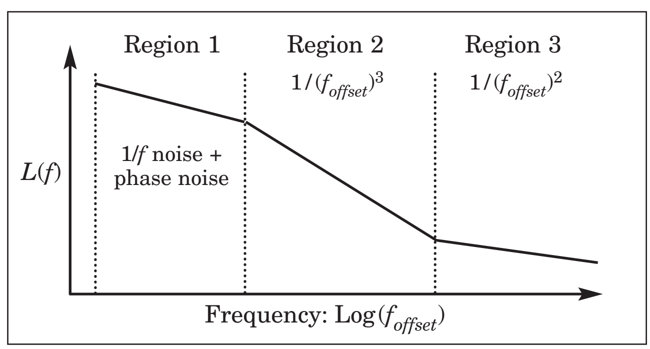

Figure 2 · Three regions with generally consistent phase noise amplitude slopes.

References

1. "Clock (CLK) Jitter and Phase Noise Conversion," Application Note 3359, Maxim Integrated Products, www.maxim-ic.com

2. Rick Poore, "Phase Noise and Jitter," Agilent Technologies, Agilent EEsof EDA, www.agilent.com