Determining Peak to Peak Frequency Jitter

Pletronics has determined that to accurately measure jitter of crystal oscillators, at or below 1 picosecond, the only method presently available is to measure phase noise and calculate RMS jitter. See our application note “Crystal Oscillators for Low Jitter Applications” for a full explanation. When measuring the phase noise of crystal oscillators, we use the two source method. This results in a single sideband measurement of phase in a 1 Hz bandwidth over a specific range of offset frequencies from the carrier. The single side band phase noise result is then integrated over a specified band of frequencies, usually 10 Hz to 1 MHz or 12 kHz to 20 MHz depending on the application. The SONET requirement bandwidth is 12 kHz to 20 MHz. This frequency domain integrated phase noise, in dBc/Hz, is then converted into a time domain RMS jitter in picoseconds. In Pletronics oscillators the RMS jitter has a random Gaussian distribution, because there are no phase locks loops used. This results in the lack of discrete spurious and multimodal non- Gaussian distribution. Hence, there is little or no deterministic jitter when powered by a low noise power supply. When the jitter has a Gaussian response, the RMS jitter is the standard deviation or one sigma value.

The crystals used in the Pletronics oscillators have a very high Q value. The loaded Q value of the oscillator resonator loop is between 10,000 to over 100,000. When the oscillator stage generates the signal, the frequency can reside anywhere within the oscillating bandwidth. However, with high Q resonators achieving a narrow oscillation bandwidth, oscillators with very low jitter can be manufactured.

With the Gaussian distribution of jitter of the Pletronics oscillators, the Mean value of the period is in the center of the Gaussian curve. Standard Deviation (1 sigma) is defined as the window that contains 68.26% of the total oscillation that occurs. This window is placed on one side of the mean. The 1 sigma (Standard Deviation) value is the RMS jitter of the oscillator output signal. As the number of Standard Deviations increases, from the Mean, the chance of the oscillator producing a signal of that period deviation is greatly reduced. At 7 sigma off-set, the chances are 100-1 x10-12 % for oscillation to occur. At 14.069 sigma, the probability is 1:1012. FIBRE Channel specifications requires 14 sigma reliability.

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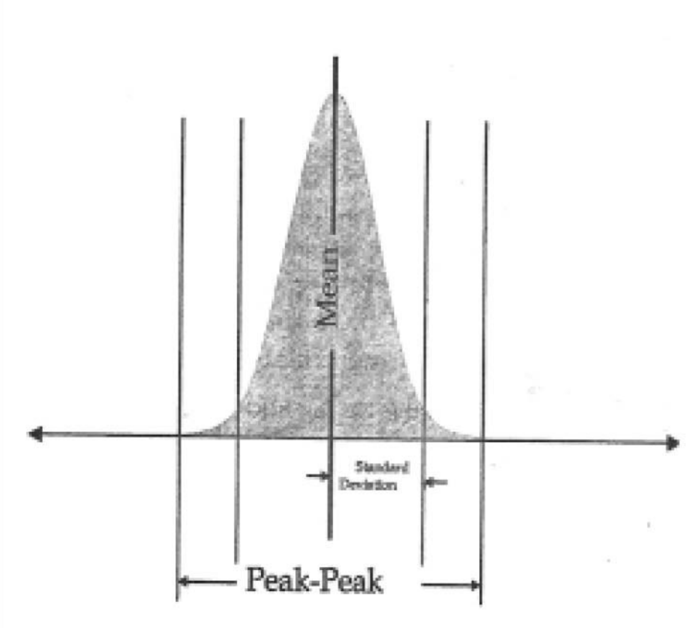
Determining the Peak to Peak (Pk to Pk) value depends on the reliability that is desired. The more reliability desired, the greater the Pk to Pk value even though the probability of occurrences greatly reduces with higher sigma values. At 14 sigma, the probability is near $1:10^{12}$. This is considered the standard we use to determine the Pk to Pk jitter from the RMS jitter value. If a Pletronics oscillator has a 2 picoseconds RMS jitter, the Pk to Pk jitter is 28 picoseconds. This is also considered the Total Jitter (TJ) due to the lack of

FIGURE 1



The following chart shows other sigma off-sets required for various probabilities:

Probability Sigma

$1:10^{8}$ 11.224

$1:10^{9}$ 11.996 $1:10^{10}$ 12.723 $1:10^{11}$

13.412 $1:10^{12}$ 14.069 $1:10^{13}$ 14.698

$1:10^{14}$ 15.301 $1:10^{15}$ 15.883 $1:10^{16}$

16.444