Custom 2-Pole PLL

TECHNICAL BRIEF

Mike Hertz,
Field Applications Engineer
Michael Schnecker,
Business Development Mgr
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Summary

This paper provides an overview of the 2nd order custom PLL, and explains how it can be applied for increased jitter measurement accuracy of serial data waveforms.

Jitter is defined as the timing uncertainty of an edge. In order to determine the timing uncertainty of a serial data signal edge, this edge must be compared to a reference clock edge.

For most high speed serial data standards, the reference clock is embedded within the serial data signal, and must be recovered from the signal under test. The method used for recovering the clock directly impacts jitter.

Many modern serial data standards define not only a standard methodology for measuring jitter, but also a standard methodology for clock recovery.

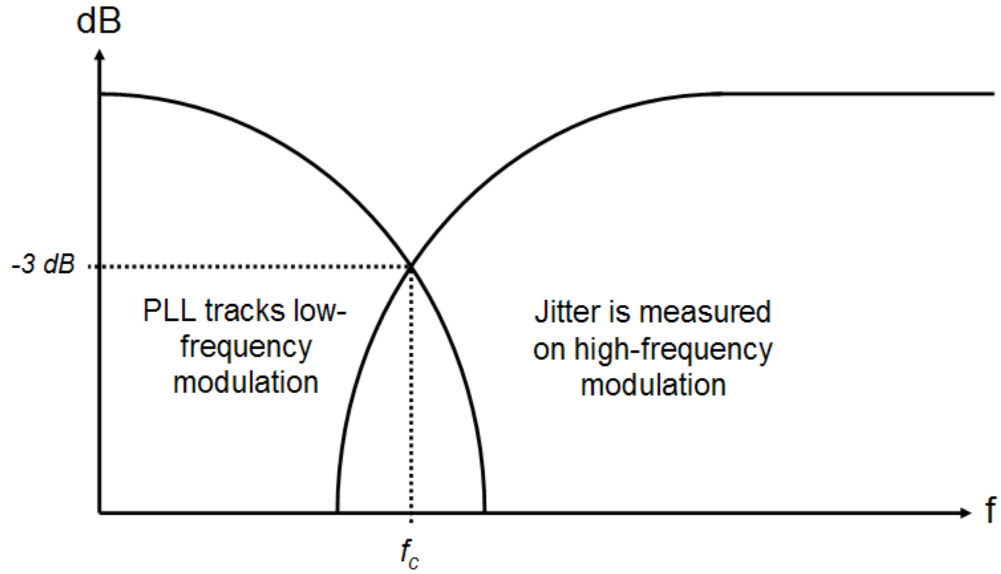
Low-frequency signal edge variations which are tracked by a PLL are not measured as jitter, because they are effectively removed by the PLL. Alternatively, low-frequency signal edge variations which are not tracked by a PLL are therefore measured as jitter. For this reason, the choice of clock recovery method affects both the PLL tracking ability as well as the total amount of jitter that can be measured.

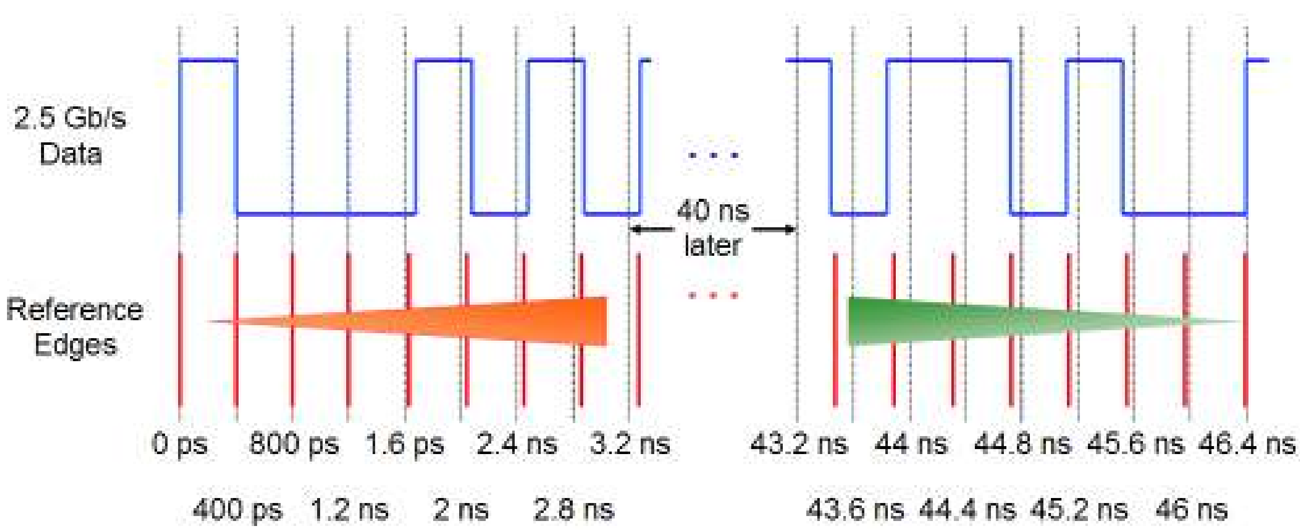
Flexible clock recovery in a jitter measurement system not only helps support the requirements of specific standards but can also be a powerful analysis tool, allowing you to predict the performance of real receivers.

How a PLL Adjusts to Signal Changes

In order to compensate for slow timing changes within the serial data stream, software clock recovery allows for the numerically-generated reference edge positions to adjust slowly over time to accommodate low frequency waveform drift, while also allowing for the measurement of high speed jitter. For example, shown in the figure below, the rate of change of reference edge timing is increased or decreased to track slow changes within the signal rate, by using a defined frequency cutoff divisor. Edge timing frequency content adjustment below the software PLL loop bandwidth is tracked, while high frequency jitter is passed through the software filter, providing for accurate high-frequency jitter measurements.

The figure below shows a single pole PLL, in which the PLL is tracking low-frequency modulation, while the high-frequency modulation is not tracked, and is instead measured as jitter. Note that the roll-off rate of a single pole low pass filter is gradual, allowing a wider range of frequencies in the crossover region, between the frequencies that are tracked and the frequencies that are measured as jitter.

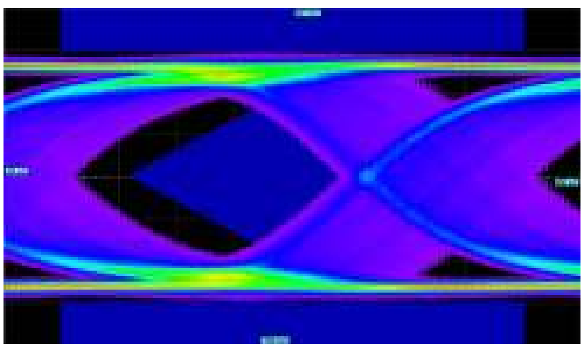




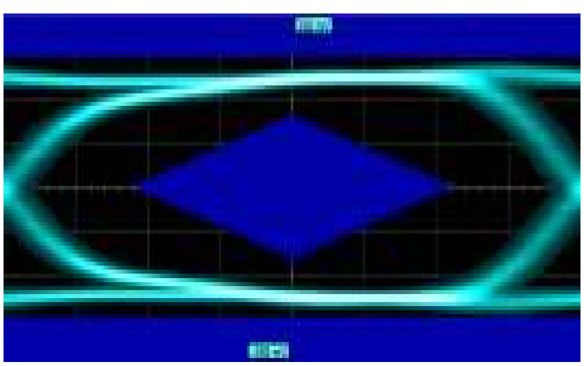
Application for a 2nd Order PLL

The relatively slow roll-off rate of the single-pole PLL imposes limitations on the jitter transfer function (JTF). In order to maintain high jitter rejection at low frequencies and to simultaneously maximize the passband of the JTF, a higher-order PLL is required.

In the case of many high speed serial data standards, such as PCI Express, Serial ATA, and SAS, spread spectrum clocking (SSC) is employed to reduce radiated emissions. The SSC modulation is in the low-frequency range of 30 - 33 kHz. Shown here is an example of a conventional eye pattern generated in the presence of SSC, without the use of a 2nd order PLL. Note that the eye pattern is modulated so significantly by the SSC, that basic jitter and eye pattern measurements are not possible.



A 2nd-order PLL allows for the user to enter the natural frequency and damping factor to reduce the size of the transition region and to maximize stop band attenuation. Shown here is the same signal with a 2nd-order PLL set to a 1 MHz natural frequency and damping factor of 0.707.



The 2-pole PLL allows for simultaneous high rejection at low frequencies, with a better jitter transfer function, and ability to track linear phase and frequency changes in the PLL passband.

Conclusion

A reference clock recovery function is an essential part of all jitter measurements. The properties of this function affect both the tracking ability as well as the amount of jitter that is measured from a serial data transmitter. Tracking is important for allowing accurate measurements in the presence of spread spectrum clocking while the high-pass cutoff frequency of the jitter transfer function of the clock recovery controls the amount of jitter that is measured. In this respect, the jitter measurement system can be made to emulate the operation of a serial data receiver. With this flexibility, real receiver performance can be accurately predicted.

References

"Clock Recovery Methods for Jitter Analysis", Michael Schnecker, 2005.