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Phase Noise Measurement Technique Using Delta-Sigma TDC Without Reference Clock

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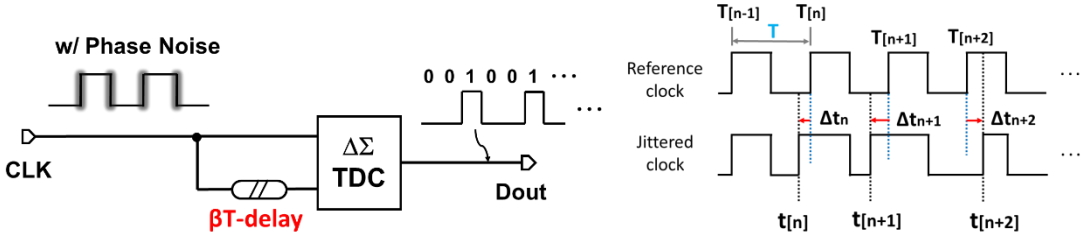
This paper describes a technique for measuring phase noise of a clock using a delta-sigma time-to-digital converter (TDC) without reference clock. The proposed technique can be implemented with relatively simple circuitry, due to the following: (i) The clock under test (CUT) is a repetitive signal. (ii) The time resolution can be increased by using longer measurement time with the delta-sigma TDC. (iii) The phase noise power spectrum can be calculated from the delta-sigma TDC output data using FFT. Costly high-performance spectrum analyzers which average several-time phase measurement results over a long measurement time (about 10s order), are not needed for phase noise measurement with the proposed technique.

Fig.1 (a) shows the proposed phase noise measurement principle using the delta-sigma TDC without a reference clock. CLK is the clock under test, which may have some phase noise, and it is delayed by $\boldsymbol{\beta}$T. Here T is the clock period, and $\boldsymbol{\beta}$ is required to be approximately one (exactly one or an integer is not necessary) and hence it is relatively easy to implement.The proposed system can measure period jitter of CLK (Fig.1(b)). We can obtain the phase noise power spectrum by multiplying the power spectrum of the period jitter obtained by FFT of the delta-sigma TDC output by $\mathbf{1}/\boldsymbol{\omega}^{\mathbf{2}}$.



(a) (b)

Fig. 1. (a) Proposed phase noise measurement using delta-sigma TDC without reference clock.
(b) Explanation of period jitter

We have confirmed the effectiveness of the proposed method by MATLAB simulation in Fig.1 (a), where the input clock frequency is set to 1MHz. Figs.2 show the simulation results with the phase variation at 10kHz. The amount of phase fluctuation obtained by simulation agreed with the theoretical calculation.

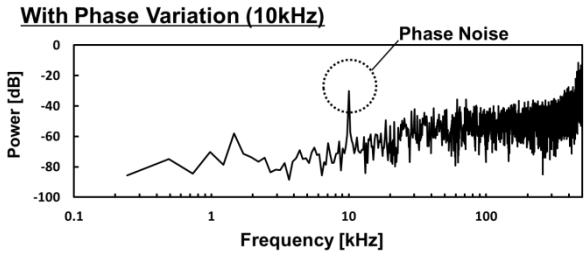


Fig.2 FFT Spectrum of output signal with phase noise at 10kHz

Reference

[1]D. Hirabayashi, Y. Osawa, N. Harigai, H. Kobayashi, et. al., "Phase Noise Measurement with Sigma-Delta TDC", IEEE International Test Conference, Poster Session, Poster No. 3, Anaheim, CA (Sept. 2013). [2]Y Osawa, D Hirabayashi, N Harigai , H Kobayashi, K Niitsu, O Kobayashi, "Phase Noise Measurement Techniques Using Delta-Sigma TDC", IEEE International Mixed-Signals, Sensors and Systems Test Workshop, Porto Alegre, Brazil (Sept. 2014).