Design of Low-Noise Bandgap References in Advanced FinFET Nodes

Design Methodology and Demonstration of Low-Noise Bandgap References using Chopper Amplifiers

Graduate

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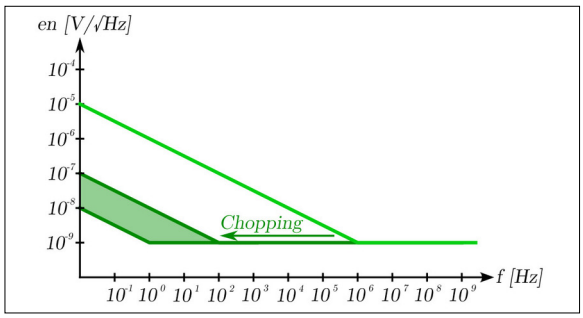
Introduction: High-speed ADCs and DACs manufactured in FinFET technologies are in part performance limited by phase-noise on the clock path. As noise on the supply is modulated onto the clock signal, low-noise supplies are required to achieve high performance. With ever improving manufacturing technology and device scaling, the influence of flicker noise will continually increase. Voltage references are therefore needed, that achieve extremely low noise in spite of the increased flicker noise intrinsic to the technology.

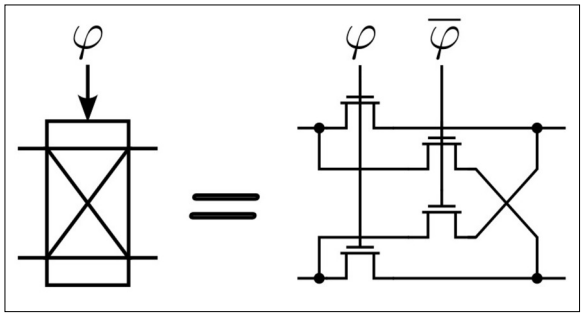
Objective: Dynamic offset cancellation techniques such as chopping and auto-zero have been known for their flicker noise reduction capabilities and have been used to great effect in amplifiers. These techniques are however rarely used in published literature as part of bandgap references. This thesis aims at incorporating these techniques into the novel application of an extremely low noise bandgap reference on a 12nm class FinFET process. As low-noise is of the utmost importance, typical design constraints such as low power consumption and high precision were neglected in favor of improvements in noise performance.

Conclusion: Two low-noise bandgap references using chopper amplifiers are presented based on the typical voltage-mode and current-mode bandgap reference circuits respectively. Performance of the voltage mode bandgap is primarily limited by the kT/C noise of the output filter and thus by the silicon area dedicated to the on-die capacitor. The circuit meets and exceeds the design goals, given a very large but realistically on-chip manufacturable capacitor, as shown in the bottom picture. The current-mode bandgap achieves good noise performance but cannot meet the ambitious performance target under any realistic design constraints. It distinguishes itself however by being more conducive for systems with multiple on chip supplies as is typical for modern ASICs. Both circuits demonstrate that flicker noise in bandgap references can be effectively minimized through the use of chopper amplifiers and thus that low noise bandgap references can be designed on modern FinFET process nodes.

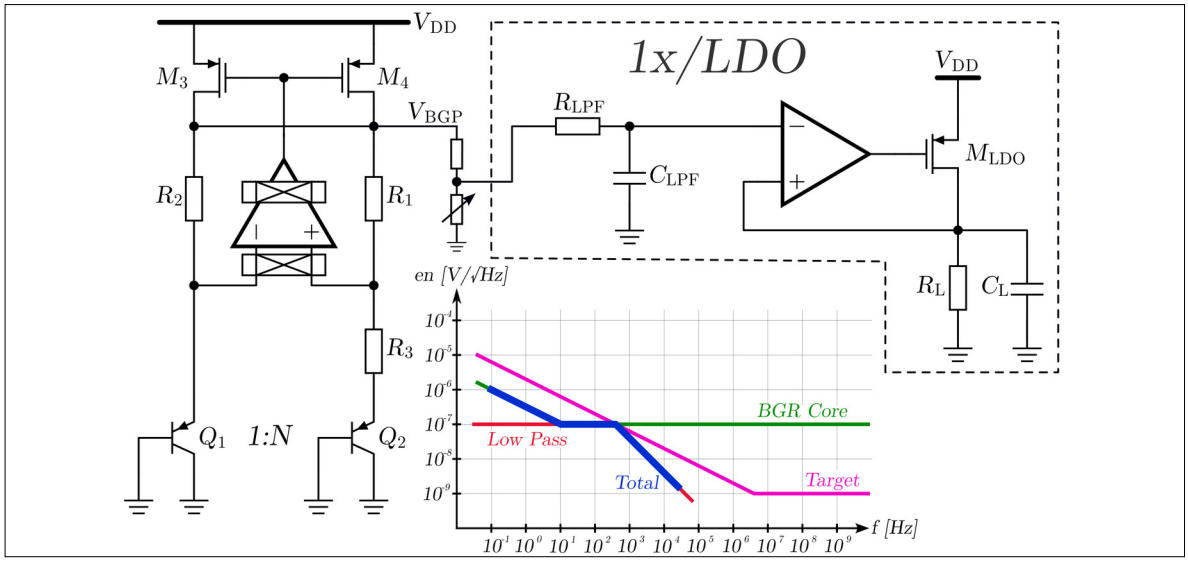
Illustration of the effect of chopping on an amplifiers noise spectral density
Own presentment



Chopper modulation block, crosses two signals every half period
Own presentment



Proposed voltage mode bandgap reference and subsequent LDO for supply voltage generation
Own presentment



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