Reference Spurs in an Integer-N Phase-Locked Loop: Analysis, Modelling and Design

by

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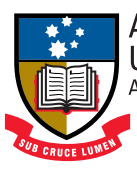

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Abstract

The Phase-Locked Loop (PLL) is commonly used for frequency synthesis in RF transceivers. It can be implemented in two architectures, namely, fractional-N and integer-N. In this thesis, the integer-N architecture is chosen due to its suitability for frequency planning.

Here, a PLL with a low noise output is important to ensure signal purity. There are two dominant noise sources in a PLL, namely, phase noise and periodic noise. In the integer-N PLL, periodic noise is also referred to as a reference spur, where the noise gives rise to multiple reference frequency offsets at the PLL output. Of these two noise sources, this thesis is focused on the analysis and suppression of reference spurs. It is because less work has been carried in the literature regarding spurs, and phase noise is better studied. The main factors underlying reference spurs are discussed. These factors are mainly from the charge pump and phase/frequency detector (PFD) circuit non-idealities, namely, PFD delay, charge pump current leakage, charge pump current mismatch, and rise and fall times characteristic of the charge pump current.

Reference spur magnitude can be predicted via a transient analysis. The simulation is time consuming, as the reference spur magnitude can only be captured after the PLL in its locked state. Therefore, the simulation period has to be set long enough to ensure enough data can be obtained to read that state. In this thesis, a reference spur mathematical analysis is presented to accurately estimate the reference spur magnitude. In the analysis, all the circuit non-idealities that contribute to the reference spur are considered. Circuit parameters required in the mathematical analysis can be obtained from transistor level simulation for each circuit. As the simulation for each circuit can be carried out separately, a large amount of simulation time can be saved. The proposed mathematical analysis also can be used to determine the major contributing factor to the problem of reference spurs.

The reference spur also can be estimated via behavioural modelling simulation. Behavioural modelling of the PLL using Simulink is presented in this thesis. Each PLL component is modelled separately, and circuit non-idealities contributing to the reference spur are included in the behavioural model. In addition to reference spur estimation,

the PLL behavioural model also can be used to visualise the dynamic behaviour of the system.

Results from the spur analysis show that a slight mismatch current in the charge pump helps to improve the reference spur performance. This thesis presents an analysis to determine an optimum charge pump current ratio for reference spur suppression, which is caused by the charge pump current mismatch and the switching delay. Further, a ratioed current charge pump circuit is proposed to replace the conventional charge pump circuit for a reference spur performance improvement. This spur suppression technique is implemented using a 180 nm SiGe BiCMOS technology for performance evaluation.

Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published written by another person, except where due reference has been made in the text.

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11th January 2013

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Noorfazila Kamal

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Thesis Conventions

The following conventions have been adopted in this Thesis:

1. **Notation.** The acronyms used in this thesis are defined in the List of Acronyms on page 169.

2. **Spelling.** Australian English spelling conventions have been used, as defined in the Macquarie English Dictionary (A. Delbridge (Ed.), Macquarie Library, North Ryde, NSW, Australia, 2001). Where two alternative spellings are allowed such as *biassing* or *biasing*, the shorter option is chosen. Also the word *analogue* is written *analog* due to its widespread usage in the engineering literature, even though it is not an Australian spelling.

3. **Typesetting.** This document was compiled using LaTeX2e. TeXnicCenter was used as text editor interfaced to LaTeX2e. TGIF was used to produce schematic diagrams and other drawings.

4. **Mathematics.** MATLAB code was written using MATLAB Version R2009a.

5. **Referencing.** The Harvard style has been adopted for referencing.

5. **Punctuation.** The Oxford convention for commas has been used for punctuation.

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Publications

KAMAL-N., AL-SARAWI S. F., AND ABBOTT-.D. (2012). An accurate analytical spur model for an integer-*N* phase-locked loop, *Proceedings of 4th International Conference on Intelligent and Advanced Systems, (ICIAS 2012)*, Vol. 2, pp. 659-664

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