Preface

Oscillatory systems exist everywhere, from our planet circulating around the sun with a period of 365.2422 days in an average tropical year; to a pendulum in an antique clock ticking every second; to the vibrations of a quartz crystal in a wrist watch. The study of oscillators was initiated centuries ago in basic mechanics. Some of the very complicated problems of injection locking in coupled oscillators were experimentally verified in the 17th century by Huygens. He used coupled pendulums using elastic threads to move energy from one pendulum to another. Oscillators belong to a class of systems known as *autonomous* systems. As opposed to driven systems, oscillators possess the unique feature that they do not need a time varying input to produce a time varying output. The periodicity and amplitude of the produced oscillation are regulated by the system's energy balance rather than an external input. This unique property makes the study of oscillators both complicated and fascinating.

In the field of electrical circuits, the study of oscillators was pioneered by radio scientists and particularly flourished during World War II. Some ingenious circuit implementations were devised to produce the best oscillators possible. Along with the circuit implementations, came the formal mathematical analysis. One of the earliest models is due to Van Der Pol in the 1920s. Rigorous nonlinear analysis was carried out throughout the 1920's until today.

Despite the long history, most of the literature, until recently, focused on two questions: 'what is the precise amplitude of oscillation?' and 'what is the exact period of oscillation?'

The question of noise behavior was addressed much later. The work of Edson was one of the earliest to discuss the output spectrum of an autonomous oscillator in circuit terms. The work of Leeson in 1964 was perhaps one of the first to address *phase* noise as a distinct class of noise in electronic oscillators and try to predict it using mathematical expressions. His *heuristic model without mathematical proof* is almost universally accepted. However, it entails a circuit specific noise factor that is not known a priori and so is not predictive.

In this work, we attempt to address the topic of oscillator design from a different perspective. By introducing a new paradigm that accurately captures the subtleties of phase noise we try to answer the question: 'why do oscillators behave in a particular way?' and 'what can be done to build an optimum design?' It is also hoped that the paradigm is useful in other areas of circuit design such as frequency synthesis and clock recovery.

In Chapter 1, a general introduction and motivation to the subject is presented. Chapter 2 summarizes the fundamentals of phase noise and timing jitter and discusses earlier works on oscillator's phase noise analysis. Chapter 3 and Chapter 4 analyze the physical mechanisms behind phase noise generation in current-biased and Colpitts oscillators. Chapter 5 discusses design trade-offs and new techniques in LC oscillator design that allows optimal design. Chapter 6 and Chapter 7 discuss a topic that is typically ignored in oscillator design. That is flicker noise in LC oscillators. Finally, Chapter 8 is dedicated to the complete analysis of the role of varactors both in tuning and AM-FM noise conversion.

In some sense, oscillators are the last of obscure analog circuits. The purpose of this book is to put together a sensible theory and optimization methodology. The objective is to lead the reader to understand and efficiently design oscillators using a mechanistic approach that does not entail complicated mathematics yet gives accurate results and design insights.

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