Preface

In the early 60s, the watchmaking industry realized that the newly invented integrated circuit technology could possibly be applied to develop electronic wristwatches. But it was immediately obvious that the precision and stability required for the time base could not be obtained by purely electronic means. A mechanical resonator had to be used, combined with a transducer. The frequency of the resonator had to be low enough to limit the power consumption at the microwatt level, but its size had to be compatible with that of the watch. After unsuccessful results with metallic resonators at sonic frequencies, efforts were concentrated on reducing the size of a quartz crystal resonator. Several solutions were developed until a standard emerged with a thin tuning fork oscillating at 32 kHz and fabricated by chemical etching. After first developments in bipolar technology, CMOS was soon identified as the best choice to limit the power consumption of the oscillator and frequency divider chain below one microwatt. Low-power oscillator circuits were developed and progressively optimized for best frequency stability, which is the main requirement for timekeeping applications. More recent applications to portable communication devices require higher frequencies and a limited level of phase noise. Micro-electro-mechanical (MEM) resonators have been developed recently. They use piezoelectric or electrostatic transduction and are therefore electrically similar to a quartz resonator.

The precision and stability of a quartz is several orders of magnitude better than that of integrated electronic components. Hence, an ideal oscillator circuit should just compensate the losses of the resonator to maintain its oscillation on a desired mode at the desired level, without affecting the frequency or the phase of the oscillation. Optimum designs aim at approaching this ideal case while minimizing the power consumption.

This book includes the experience accumulated along more than 30 years by the author and his coworkers. The main part is dedicated to variants of the Pierce oscillator most frequently used in timekeeping applications. Other forms of oscillators that became important for RF applications have been added, as well as an analysis of phase noise. The knowledge is formalized in an analytical manner, in order to highlight the effect and the importance of the various design parameters. Computer simulations are limited to particular examples but have been used to crosscheck most of the analytical results.

Many collaborators of CEH (Centre Electronique Hologer, Watchmakers Electronic Center), and later of CSEM, have contributed to the know-how described in this book. Among them, by alphabetic order, Daniel Aebischer, Luc Astier, Serge Bitz, Marc Degrauwe, Christian Enz, Jean Fellrath, Armin Frei, Walter Hammer, Jean Hermann, Vincent von Kaenel, Henri Oguey, and David Ruffieux. Special thanks go to Christian Enz for the numerous discussions about oscillators and phase noise during the elaboration of this book.

Eric A. Vittoz
Cernier, Switzerland
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Vittoz, E.
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