Colpitts Oscillator

4

1 Introduction

The universe of oscillators can be divided between the differential LC oscillator, where the zero crossing of the oscillating voltage switches the active devices, and the Colpitts oscillator, where only the peaks of the oscillation voltage inject current from the active device.

Historically, when transistors were expensive, the Colpitts oscillator was the topology of choice because it required only a single transistor [1]. Now that transistors are essentially free, the Colpitts oscillator remains popular because it only requires a single pin to connect to an external resonator and no coupled inductors. However, its steady state behavior is poorly understood, and its phase noise is outright misunderstood.

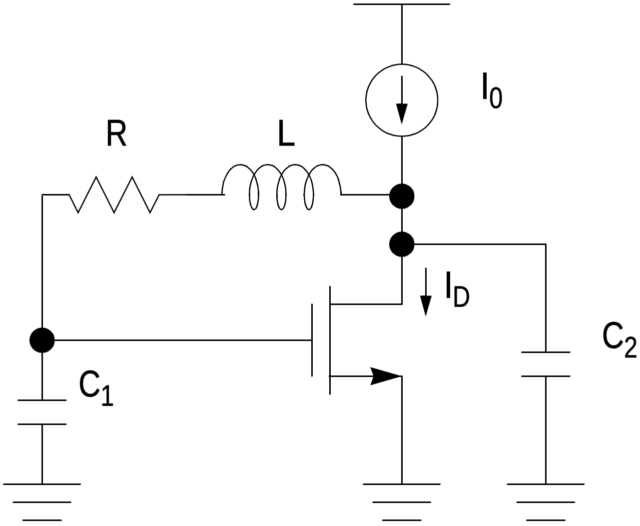
Using complicated mathematical expressions, Huang analyzed the phase noise of the Colpitts oscillator in 1998 [2]. He gave a detailed analysis of the Colpitts oscillator and his methods served as a motivation for this work. In this chapter, the techniques developed in Chapter 3 are used to simplify the analysis of phase noise in the white noise region. As a historical note, Kulagin analyzed the Colpitts oscillator in a similar manner [1]. He specifically looked at a Colpitts oscillator with automatic gain control.

2 Steady-State

Figure 1 shows the Colpitts oscillator that is analyzed. This topology is exactly the same as the circuit analyzed by Huang except the location of the ground node has been moved to the source terminal. This change greatly simplifies the analysis.

The analysis begins with a large-signal steady-state analysis. Once oscillation starts, the capacitors charge up to a DC voltage which biases the transistor in a nominally off position. The amplitude builds up to a point such that the peaks of the oscillation voltage across capacitor C_1 turn on the transistor for a conduction angle, θ, which is a fraction of the phase of one period, 2π, Figure 2c. "Steady-state" implies the selection of θ such that various circuit constraints are met. First, the average current through the transistor must equal the bias current I_0 because the capacitors cannot carry DC current. Second, the fundamental component of the periodic transistor current, I_D, must support the amplitude across C_1 responsible for setting θ.

FIGURE 1 *Schematic of a Colpitts oscillator. The noise in the oscillator is modeled as a current source in parallel with the bias current source.*



As in the analyses of other large-signal circuits, the transistor characteristics are simplified to capture its essential action. Here, the simplification entails representing it as a constant transconductance, g_m, above a threshold V_T, Figure 2a. The transistor carries an average current I_{D0} while its physics and/or its aspect ratio will determine g_m. Eventually g_m will be represented in terms of θ. To further simplify the analysis, the output voltage is taken as the voltage across C_1 and it is assumed to consist of an oscillation and DC component, (1).