Due to their relatively good phase noise, ease of implementation and differential operation, cross-coupled LC oscillators play an important role in high frequency circuit design [51]-[56]. This chapter presents analysis and design implications in complementary cross-coupled differential oscillator [52][55]. A simple expression for the tank amplitude is obtained in Section 6.1. The effect of different noise sources in such oscillators is investigated and methods for exploiting the cyclostationary properties of noise are shown in Section 6.2. The effect of tail current noise is the subject of Section 6.3. New design implications arising from this approach and experimental results are given in Section 6.4.

6.1 Tank Amplitude

Tank voltage amplitude has an important effect on the phase noise, as emphasized by the presence of $q_{\text{max}}$ in the denominator of (4.16). A simple expression for the tank amplitude can be obtained by assuming that the differential stage switches quickly from one side to another\(^1\). Figure 6.1 shows the current flowing in the complementary cross-coupled differential LC oscillator [52][55] when it is completely switched to

\(^1\) A more general describing function analysis of the oscillation amplitude can be found in Appendix F.
one side. As the tank voltage changes, the direction of the current flow through the tank reverses. The differential pair thus can be modeled as a current source switching between $I_{\text{tail}}$ and $-I_{\text{tail}}$ in parallel with an RLC tank, as shown in Figure 6.2. $R_{eq}$ is the equivalent parallel resistance of the tank.

At the frequency of resonance, the admittances of the $L$ and $C$ cancel, leaving $R_{eq}$. Harmonics of the input current are strongly attenuated by the $LC$ tank, leaving the fundamental of the input current to induce a differential voltage swing of amplitude $(4/\pi)I_{\text{tail}}R_{eq}$ across the tank if one assumes a rectangular current waveform. At high frequencies, the current waveform may be approximated more closely by a sinusoid due to finite switching time and limited gain. In such cases, the tank amplitude can be better approximated as