3 Current Biased Oscillator

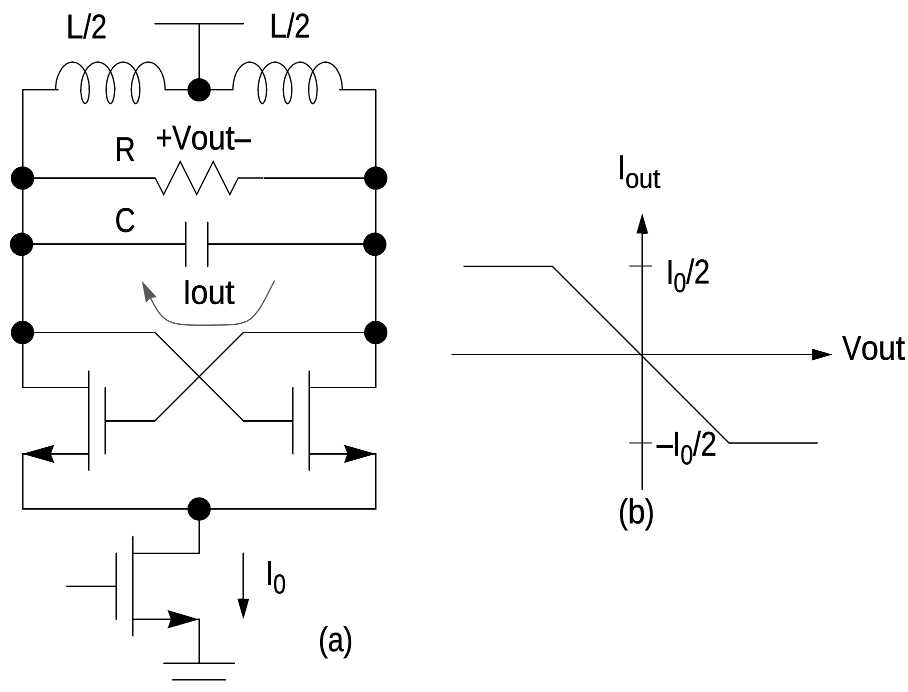
The well-known tail-current biased differential LC oscillator is analyzed in this chapter. This oscillator is very popular and has been analyzed by many people [1,2]. Because it is a truly-differential circuit, the analysis here is greatly simplified.

1 Steady-State Operation

The tail-current biased differential LC oscillator is shown in Figure 1a. It consists of a differential pair, which commutates a tail current to provide an effective negative resistance across the resonator. The resonator is drawn as shown because differential inductors provide a higher Q and consume a smaller area than single-ended inductors. The I-V characteristic of the cross-coupled differential pair characteristic is shown in a piecewise linear fashion in Figure 1b. In the linear region, the I-V characteristic has a negative slope that corresponds to the negative resistance of the device. The curve then flattens out and the effective admittance is zero. In this region, the circuit does not provide any negative resistance nor does it provide a loss that would load the resonator. The curve does not have any hysteresis or “loops” and so indicates that the circuit is memoryless.

In steady-state, the oscillation switches this differential pair to produce a differential square-wave current at the output that excites the resonator, making up for losses in the resistor, Figure 2a. The square wave has a frequency spectrum consisting of a fundamental, with amplitude $2I_0/\pi$, and odd harmonics. The resonator filters out the higher harmonics and the fundamental flows through the resistors, with a value R, to determine the differential steady-state amplitude of oscillation. The amplitude is given in (1) and is shown graphically in Figure 2b, [3]. Note that the current in each of the switching transistors switches between 0 and I_0 with a bias value of $I_0/2$. The *signal* current

FIGURE 1 *(a) A cross-coupled differential oscillator and (b) the differential IV characteristic of the cross-coupled differential pair.*



into the differential tank resistance is thus switching between $I_0/2$ and $-I_0/2$. Some references use a different notation where the output current is taken as the difference between the currents in each side of the oscillator. In that case, the switching waveform moves between $-I_0$ and I_0 but flows into $R/2$ to build the amplitude.

$$V_{out} = \frac{2}{\pi} R I_0 \quad (1)$$

The frequency of oscillation is determined by the resonator and occurs when the energy in the inductor is balanced by the energy in the capacitor. If the current flowing into the resonator consists of only a sinewave, the balance occurs at the resonance frequency of the tank.