1. **Suppose in Fig. 5.1, the LNA has a voltage gain of A_0 and the mixers have a high input impedance and a voltage gain of unity. If the I and Q outputs are simply added, determine the overall noise figure in terms of the NF of the LNA and the input-referred noise voltage of the mixers.**

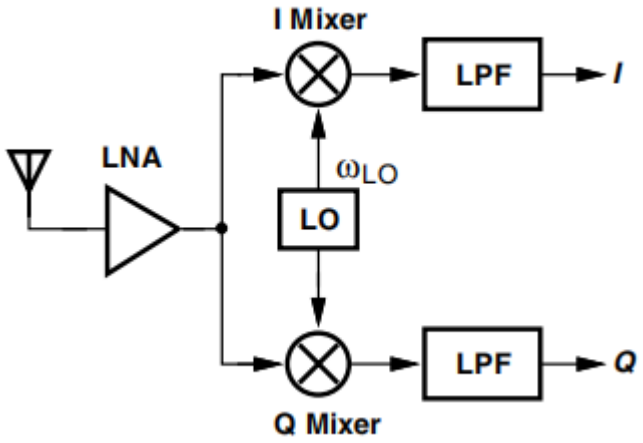

Fig. 5.1

The NF of the LNA:

$$NF_1 = 1 + \frac{\overline{V_{n,out,LNA}^2}}{A_0^2} \cdot \frac{1}{4kTR_s}$$

$$\Rightarrow \overline{V_{n,out,LNA}^2} = (NF_1 - 1) \cdot A_0^2 \cdot 4kTR_s$$

$$\overline{V_{n,out}^2} = \overline{V_{n,out,LNA}^2} + 1 \cdot \overline{V_{n,in,\,I\,mixer}^2} \cdot 2$$

$$\Rightarrow NF_{total} = 1 + \frac{(NF_1 - 1)A_0^2 \cdot 4kTR_s + 2 \cdot \overline{V_{n,in,\,I\,mixer}^2}}{A_0^2} \cdot \frac{1}{4kTR_s}$$

2. Consider the circuit of Fig. 5.2, where C1 and C2 are identical and represent the gate-source capacitances in Fig. 5.3. Assume $V_1 = -V_2 = V_0 cos\omega_{LO} t$.

   a) If $C_1 = C_2 = C_0(1 + \alpha_1 V)$, where V denotes the voltage across each capacitor, determine the LO feedthrough component(s) in V_{out}. Assume $\alpha_1 V \ll 1$.

   b) Repeat part (a) if $C_1 = C_2 = C_0\left(1 + \alpha_1 V + \alpha_2 V^2\right)$.

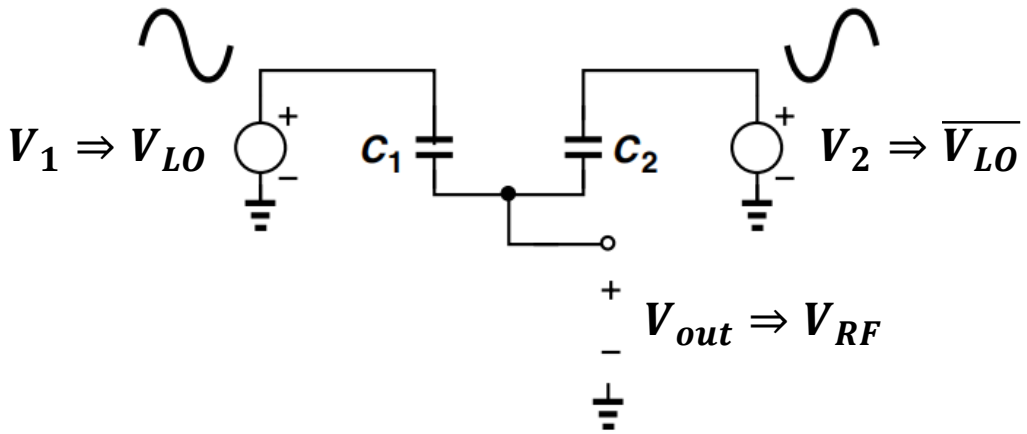

Fig. 5.2

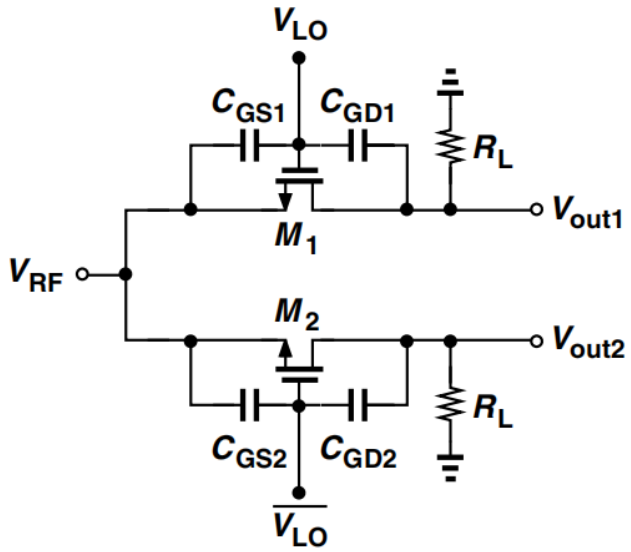

Fig. 5.3

2. **Consider the circuit of Fig. 5.2, where C1 and C2 are identical and represent the gate-source capacitances in Fig. 5.3. Assume $V_1 = -V_2 = V_0 cos\omega_{LO} t$.**

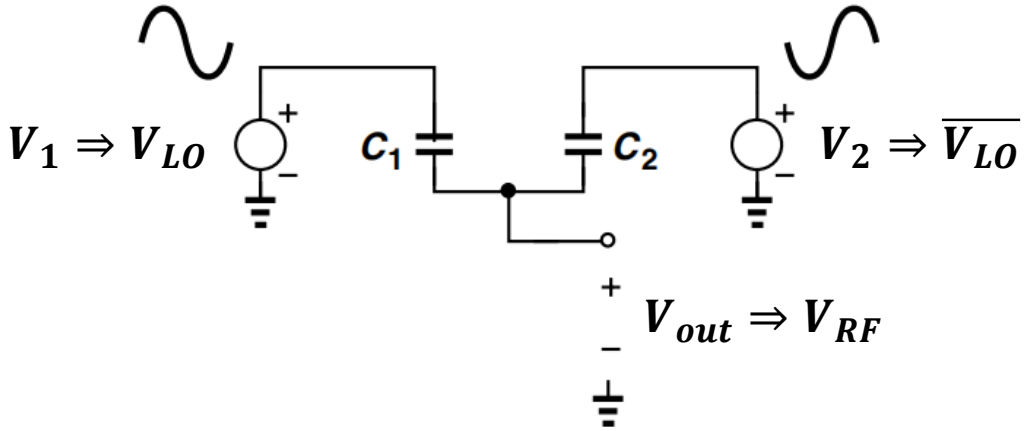

Fig. 5.2

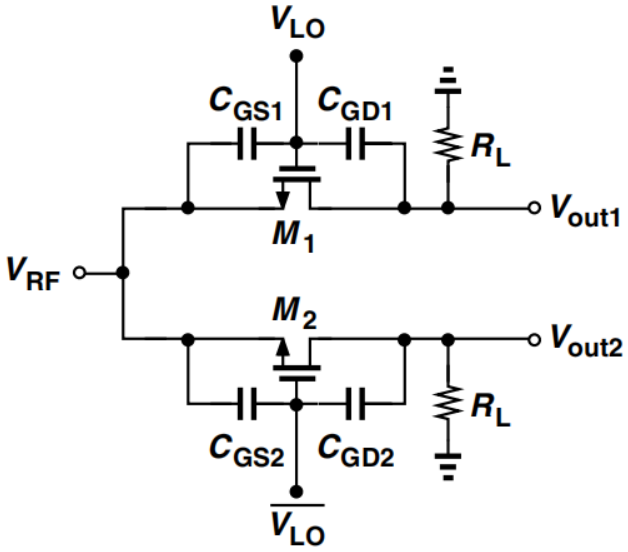

Fig. 5.3

(a)

$$V_{out} = V_1 \cdot \frac{C_1}{C_1 + C_2} + V_2 \cdot \frac{C_2}{C_1 + C_2} = V_0 cos\omega_{LO} t \cdot \frac{C_1 - C_2}{C_1 + C_2} = 0$$

for single-balanced mixer, the LO-RF feedthrough at ω_{LO} vanishes if the circuit is symmetric

(b)

the result is the same as (a) because of symmetry