1. In the active mixer of Fig. 6.1, $I_{n,M1}$ contains all frequency components. Prove that the convolution of these components with the harmonics of the LO in essence multiplies $4kT\gamma/g_m$ by a factor of $\pi^2/4$.

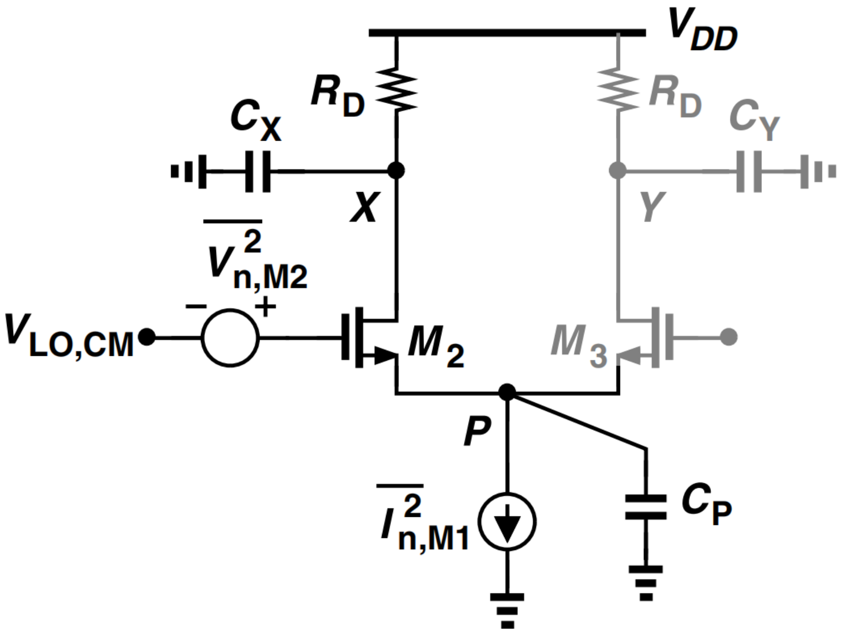
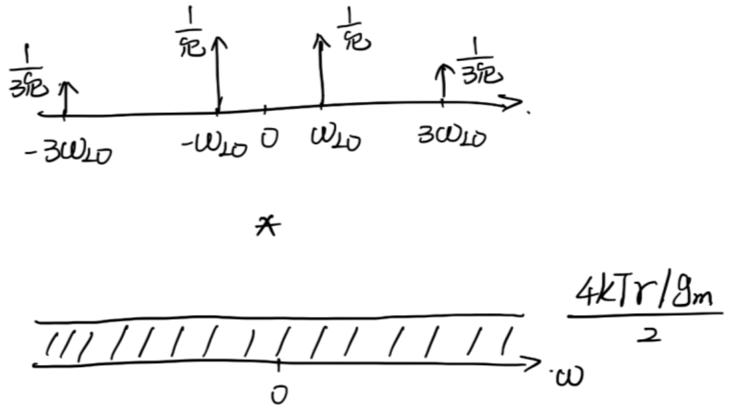


Fig. 6.1

LO: 50% duty cycle square wave



$$\frac{4kT\gamma/g_m}{2}\cdot\left[\frac{1}{\pi^2}+\frac{1}{(3\pi)^2}+\frac{1}{(5\pi)^2}+\cdots\right]=\frac{4kT\gamma}{g_m}\cdot\frac{1}{\pi^2}\cdot\frac{\pi^2}{16}$$

As there are two sides on the spectrum and two sides in the mixer

$$\Rightarrow 4kT\gamma/g_m\cdot\frac{1}{\pi^2}\cdot\frac{\pi^2}{4}$$

2. Shown in Fig. 6.2 is the front end of a 1.8-GHz receiver. The LO frequency is chosen to be 900 MHz and the load inductors and capacitances resonate with a quality factor of Q at the IF. Assume M_1 is biased at a current of I_1, and the mixer and the LO are perfectly symmetric.

   a) Assuming M_2 and M_3 switch abruptly and completely, compute the LO-IF feedthrough, i.e., the measured level of the 900-MHz output component in the absence of an RF signal.

   b) Explain why the flicker noise of M_1 is critical here.

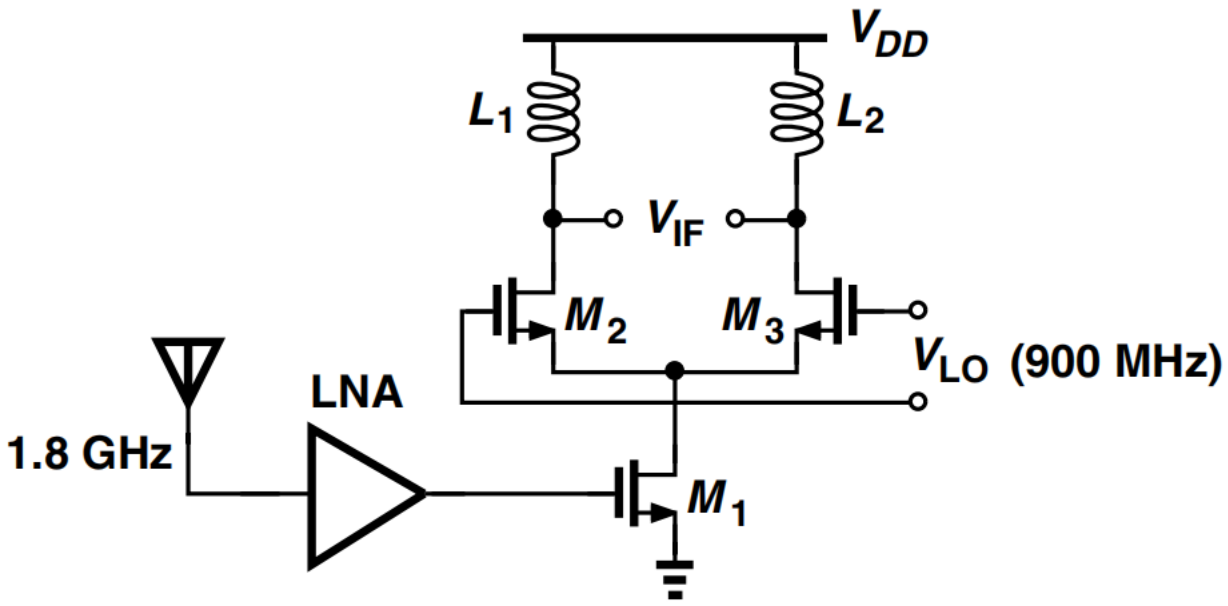


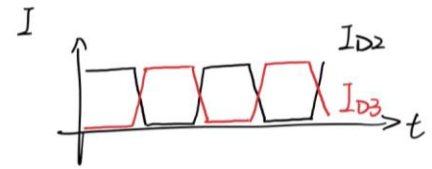
Fig. 6.2

2. Shown in Fig. 6.2 is the front end of a 1.8-GHz receiver. The LO frequency is chosen to be 900 MHz and the load inductors and capacitances resonate with a quality factor of Q at the IF. Assume M_1 is biased at a current of I_1, and the mixer and the LO are perfectly symmetric.

   a) Assuming M_2 and M_3 switch abruptly and completely, compute the LO-IF feedthrough, i.e., the measured level of the 900-MHz output component in the absence of an RF signal.

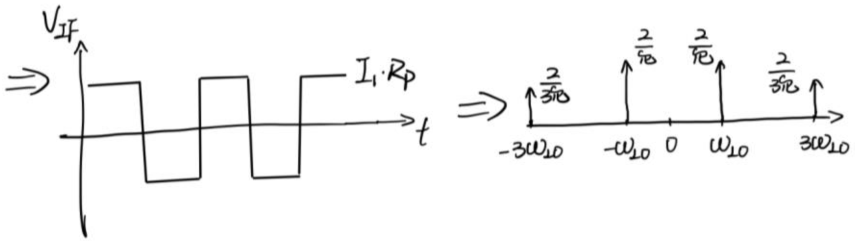
   b) Explain why the flicker noise of M_1 is critical here.

a)



$V_{IF} = (V_{DD} - I_{D3} \cdot R_p) - (V_{DD} - I_{D2} \cdot R_p) = (I_{D2} - I_{D3}) \cdot R_p$.

$\Rightarrow$

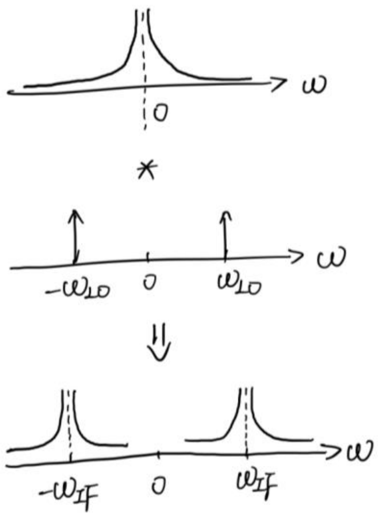


$\therefore$ LO-IF feedthrough

$= I_1 \cdot R_p \cdot \frac{4}{\pi} = I_1 \omega_0 L_1 Q \cdot \frac{4}{\pi}$

b)

$\because$ flicker noise of M_1 :



So the flicker noise is transferred to IF band