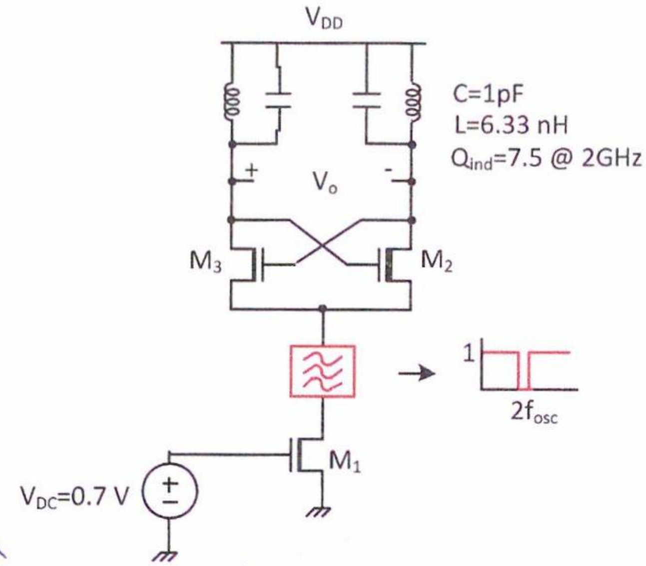
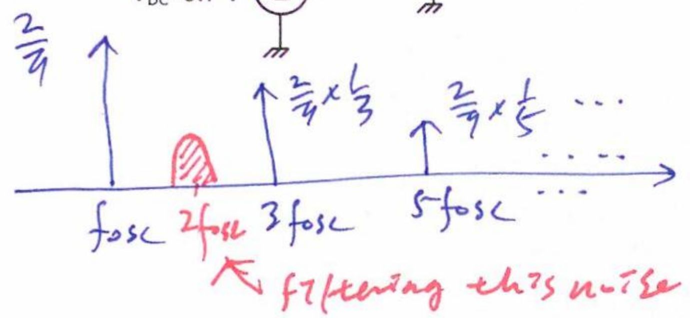
5) Now, let's use ideal filter which will reject noise at $2\mathrm{x}f_{osc}$ from M1 completely (f_{osc} is output oscillation frequency). Assume the filter is noiseless. Calculate phase noise contribution from M1 at 10MHz offset. How much improvement will it achieve compared with 3) through filtering the second harmonic noise? (20 pt).





$$\overline{i_{no}^2} = 4KT\frac{\gamma}{\alpha} g_{m1}\left(1-\left(\frac{2}{\pi}\right)^2\left(1^2+\frac{1}{3}^2\right)\right)$$

double side band noise per tone

details ⇒ $$\overline{i_{no}^2} = \underbrace{2}_{\text{2-sided spectrum}} \times \underbrace{2KT\frac{\gamma}{\alpha} g_m}_{\text{1-side noise current power}} \left(\frac{2}{\pi}\right)^2 \Big\{ \underbrace{\sum_{n=1}^{\infty}\left(1+\frac{1}{3}^2+\frac{1}{5}^2+\frac{1}{7}^2+\dots\right)\times 2}_{\text{power of fundamental \& harmonic tones}} - \underbrace{\left(1+\frac{1}{3}^2\right)}_{\text{rejection by filtering}} \Big\}$$

$$= 4KT\frac{\gamma}{\alpha} g_m - 4KT\frac{\gamma}{\alpha} g_m \left(\frac{2}{\pi}\right)^2\left(1+\frac{1}{3}^2\right)$$

$$\therefore \left(\overline{\Phi_n^2}\right)_{\text{due to } M1} = \left(\frac{1}{2Q\frac{\Delta\omega}{\omega_0}}\right)^2 \frac{4KT\frac{\gamma}{\alpha} g_m R_L^2\left(1-\left(\frac{2}{\pi}\right)^2\left(1+\frac{1}{9}\right)\right)}{\frac{1}{2}V_p^2\times 4}$$

$$= 10.958\times 10^{-11}\ \text{rad}^2/\text{Hz} = -139.6\ \text{dBc/Hz}$$

⇒ 2.6 dB improvement.