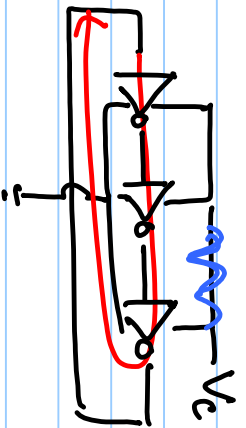
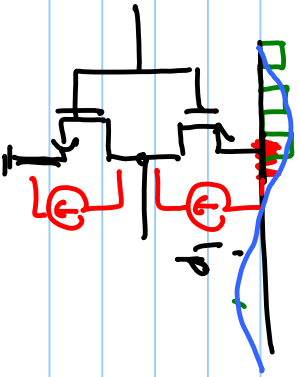
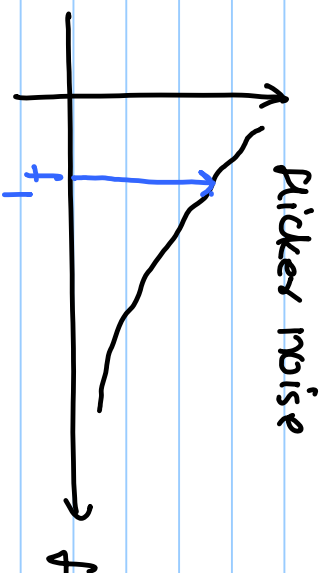


# Lecture #31



$$f_{out} = K_{vco} \cdot \underline{V_c} \checkmark$$

$$\frac{df_o}{dv_c} = K_{vco} \checkmark$$



$$S_{f_o}(f) = K_{vco}^2 S_{v_c}(f) \Rightarrow L(f) = \left( \frac{K_{vco}^2}{4f^2} \right) S_{v_c}(f) \checkmark$$

$$T = \frac{C_{VDD}}{2} \left[ \frac{1}{I_{NI}} + \frac{1}{I_{PI}} + \dots + \frac{1}{I_{NM}} + \frac{1}{I_{PM}} \right] \checkmark$$

$$f_0 = \frac{1}{T} = \frac{2}{C_{VDD}} \left[ \dots \right]^{-1} \checkmark$$

$$\frac{df_0}{I_{NRc}} = \frac{2}{C_{VDD}} \left[ \left( \sum_{j=1}^M \frac{1}{I_{Nj}} + \frac{1}{I_{Pj}} \right)^{-2} \right] \frac{1}{I_{NRc}^2}$$

$$I_{Nj} = I_{Pj} = I$$

$$= \frac{C_{VDD} f_0^2}{2 I_{NRc}^2} = \frac{f_0}{2MI}$$

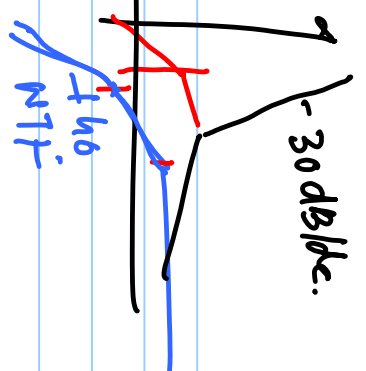
$$L(f) = \frac{1}{4f^2} \left( \frac{f_0}{2MI} \right)^2 S_{in}^{1/f}(f)$$

$$\text{Total } L(f) = \frac{1}{4f^2} \left( \frac{f_0}{2MI} \right)^2 \times M \left( S_{in}^{1/f} + S_{in}^{Vt} \right)$$

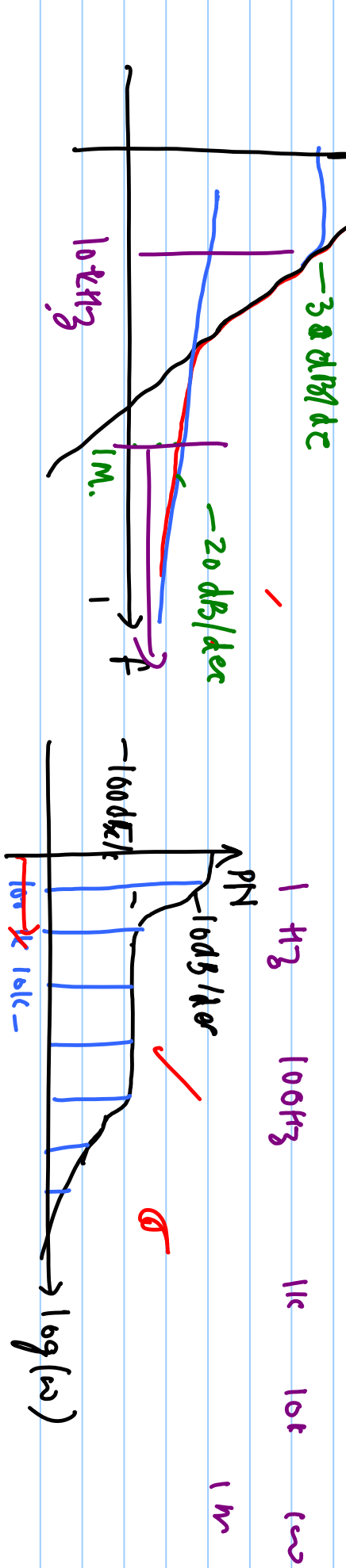
$$= \frac{1}{16MI^2} \left( S_{in}^{1/f} + S_{in}^{Vt} \right) \left( \frac{f_0}{f} \right)^2$$

$$S_{in}^{1/f} = g_m^2 S_{vn}^{1/f} = \left( \frac{2I}{V_{DD} - V_t} \right)^2 \frac{K_{tn}}{WL C_0 \times f}$$

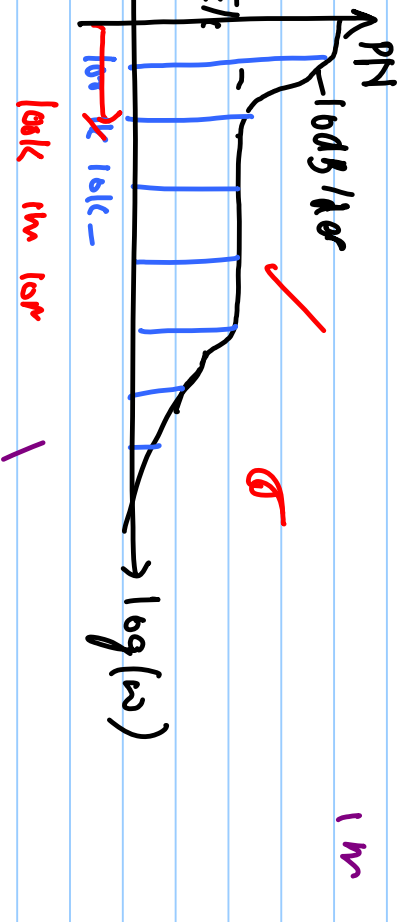
$$Z(f) = \frac{1}{4M(V_{DD}-V_t)^2} \left( \frac{K_{tN}}{W_N L_N} + \frac{K_{pP}}{W_P L_P} \right) \frac{f_0^2}{f^3}$$

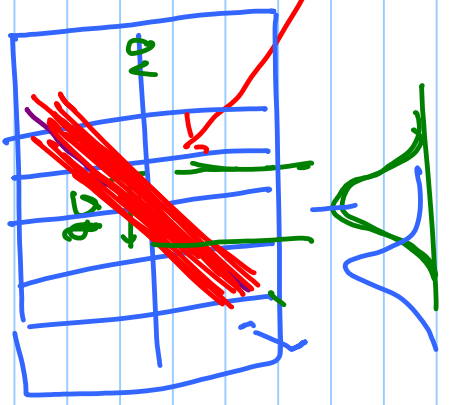
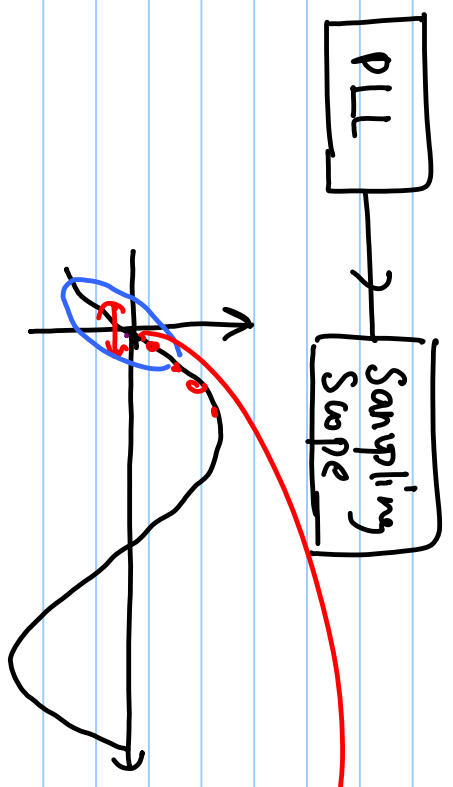
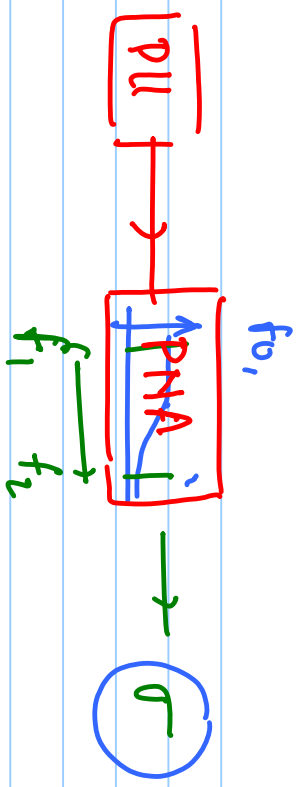


$$= \frac{C_{ox}}{8MI} \left( \frac{\mu_n K_{tN}}{L_N^2} + \frac{\mu_p K_{pP}}{L_P^2} \right) \frac{f_0^2}{f^3} \Rightarrow -30 \text{ dB/dec.}$$



PLL Phase Noise





100 samples —  $\sigma$

$\Delta t_i \rightarrow \mu, \sigma$   
 $\downarrow$   
 max, min  
 peak-to-peak