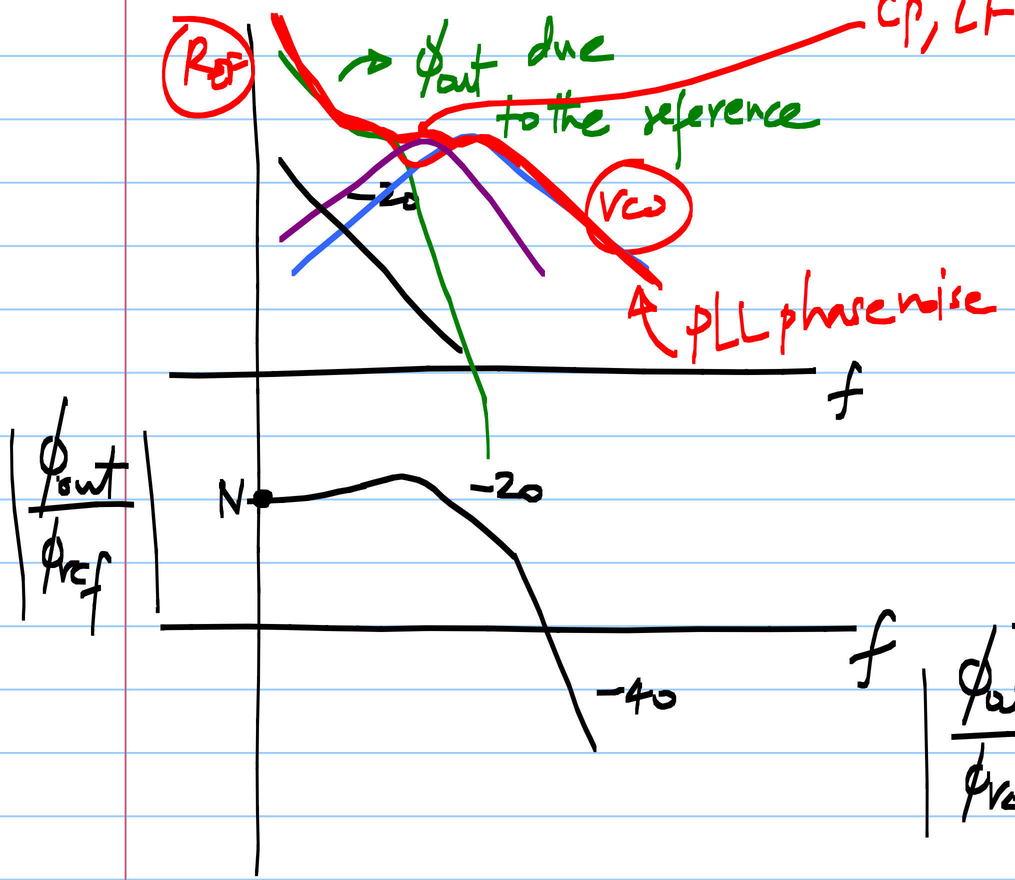
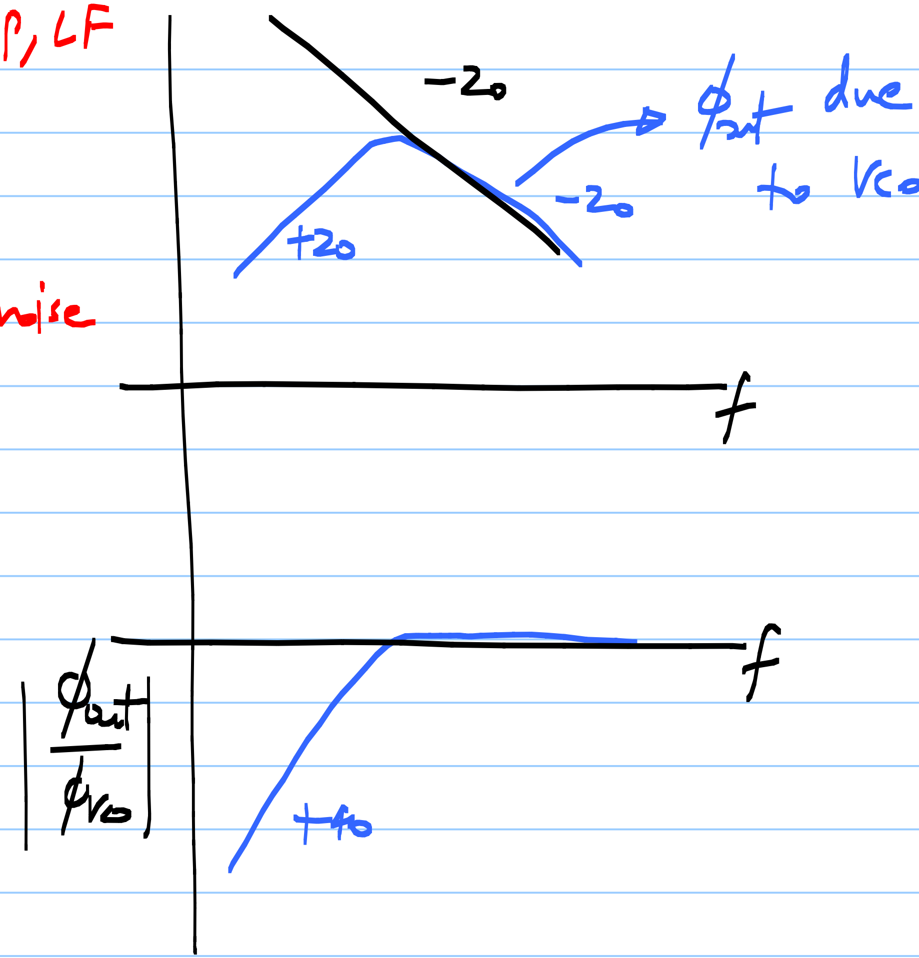
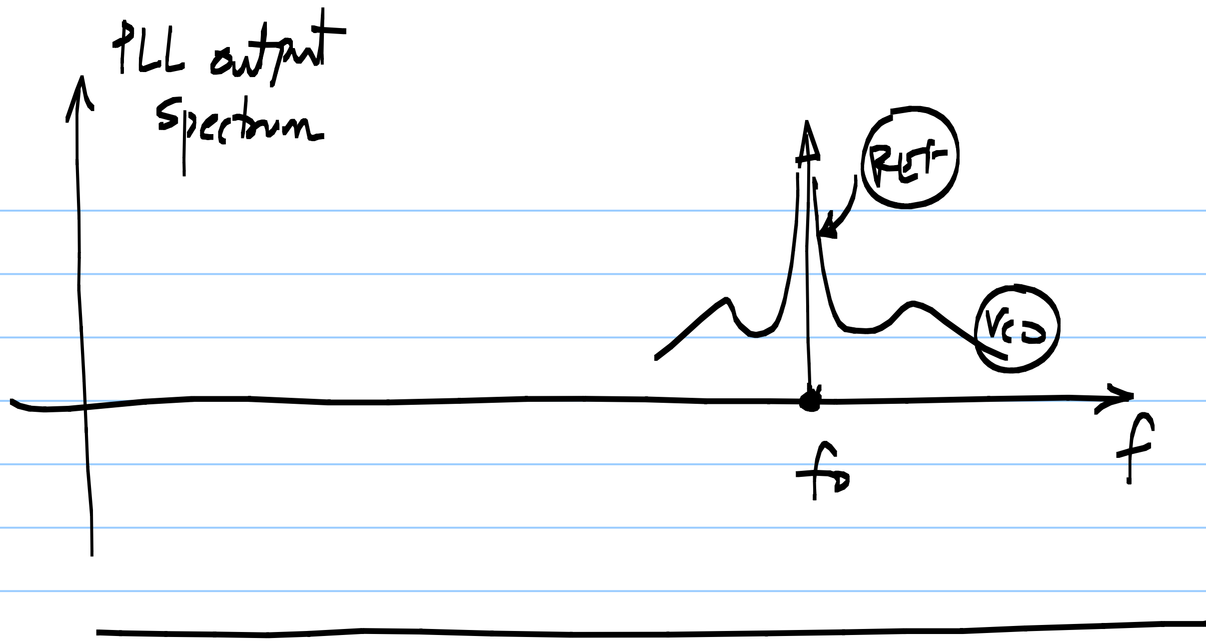
Lecture 52 PLL phase noise





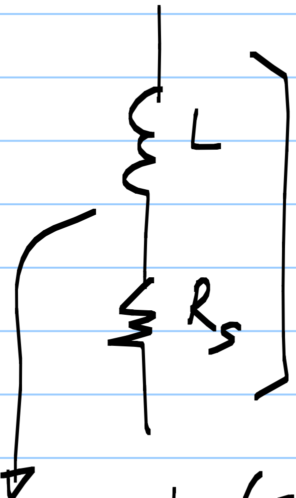

PLL output
Spectrum
REF
VCO
f_0
f

Voltage controlled oscillator

* LC oscillators : cross coupled pair ✓
  Colpitts, Hartley oscillators

* Ring oscillators :
  • CMOS inverter ring oscillator
  • Current starved ring oscillator
  • CML (differential) ring oscillator

LC oscillator:



$$Z = R_s + j\omega L$$

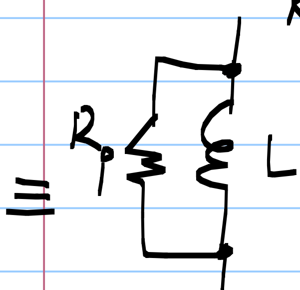
$$Y = \frac{1}{R_s + j\omega L} = \frac{R_s - j\omega L}{R_s^2 + \omega^2 L^2} = \frac{R_s}{R_s^2 + \omega^2 L^2} - j\,\frac{\omega L}{R_s^2 + \omega^2 L^2}$$

If $Q \gg 1$ $\{\ \omega L \gg R_s\}$

$$Q : \frac{\mathrm{Im}(Z)}{\mathrm{Re}(Z)} = \frac{\omega L}{R_s}$$

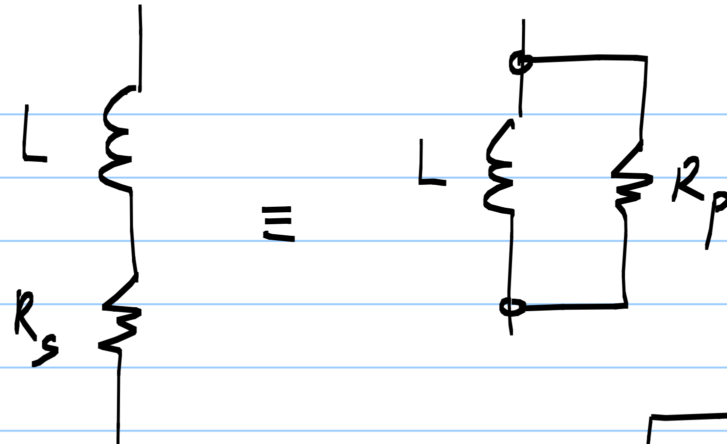
$$Y \simeq \underbrace{\frac{R_s}{\omega^2 L^2}}_{} - \underbrace{\frac{j}{\omega L}}_{}$$

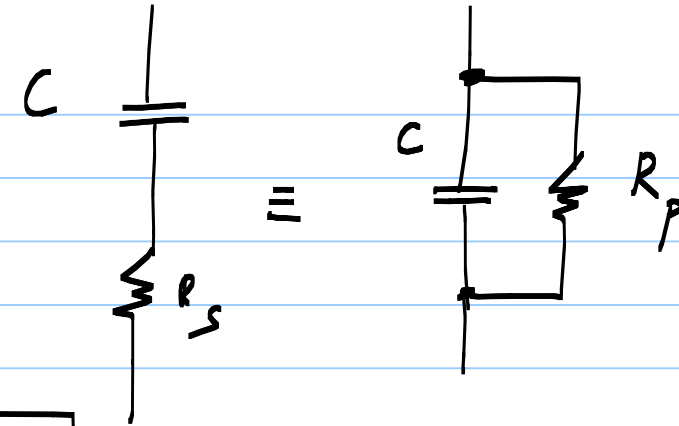
$$\simeq \frac{1}{R_p} + \frac{1}{j\omega L}$$



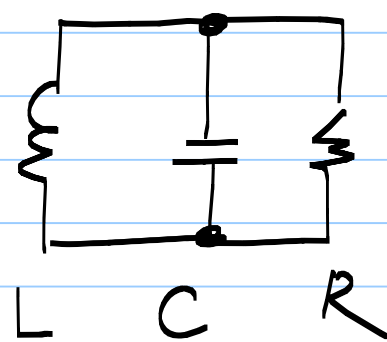
$$R_p = \frac{\omega_o^2 L^2}{R_s} = Q^2 R_s$$

$Q = \omega L / R_s$ $\qquad$ $Q = R_p / \omega L$ $\qquad$ $Q = \dfrac{1}{\omega C R_s}$ $\qquad$ $Q = \omega C R_p$

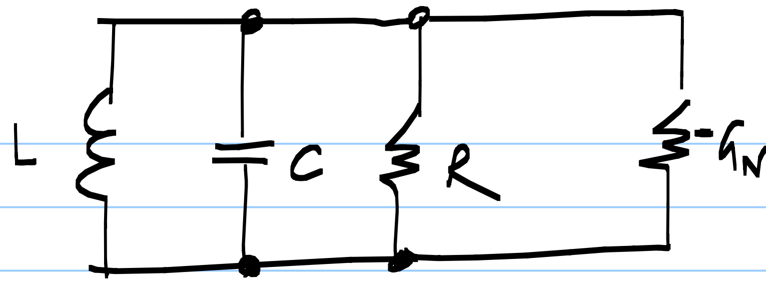




$$\boxed{R_p = Q^2 \cdot R_s}$$



[loss of L, C]



If $G_N = G_P$,

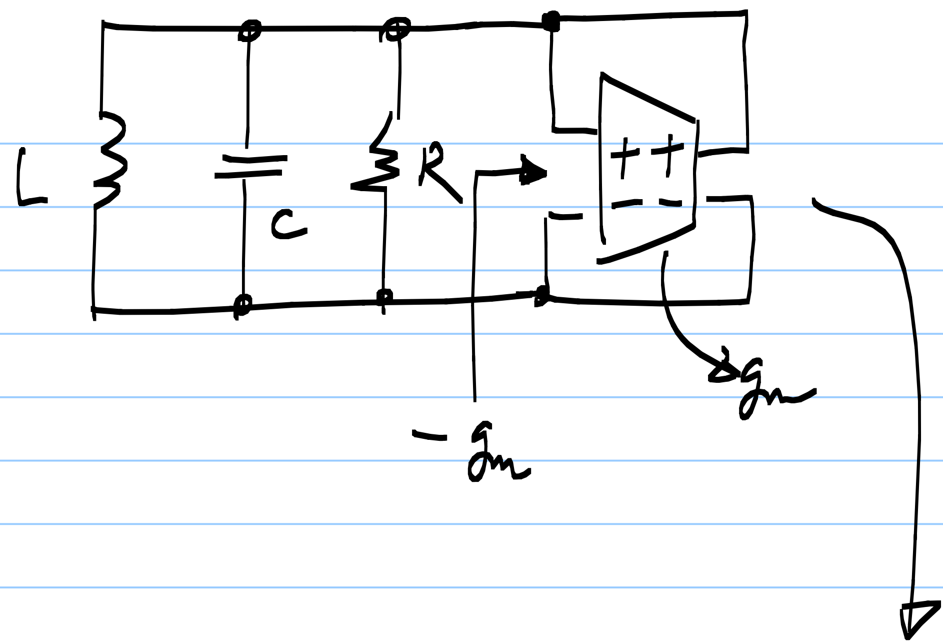
lossless LC

$\frac{1}{R} = G_P$

$G_N < G_P$: lossy ; oscillations die out

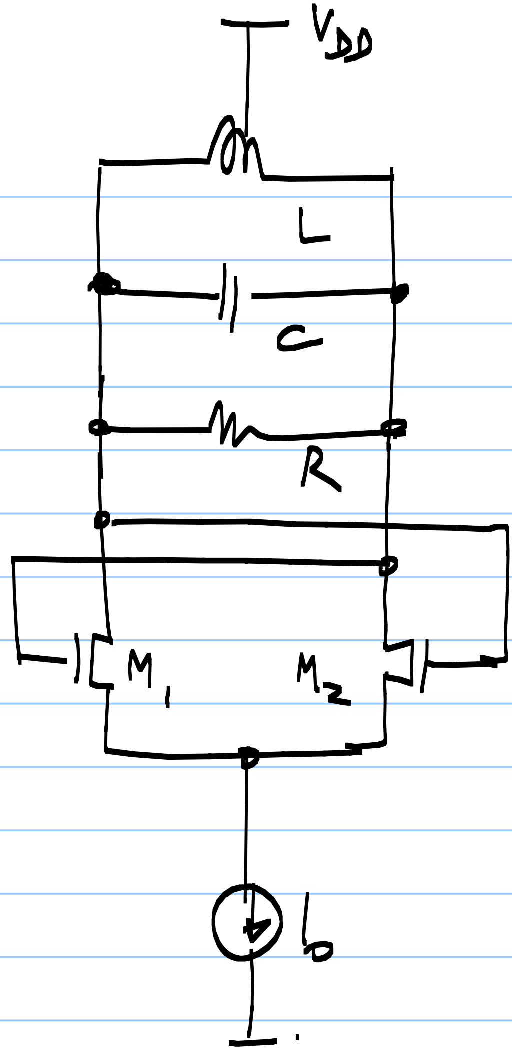
$G_N = G_P$: lossless ; sustained oscillations at a constant amplitude

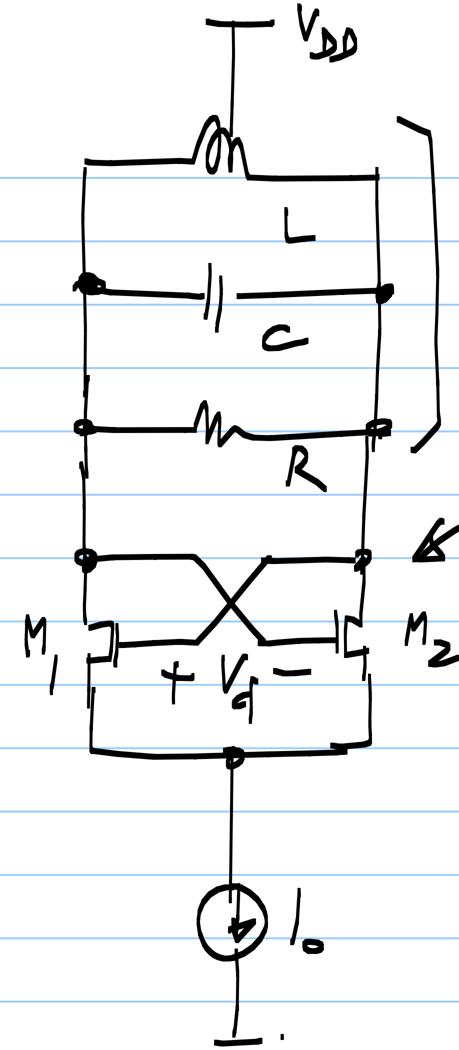
$G_N > G_P$: regenerative ; Oscillations with increasing amplitude

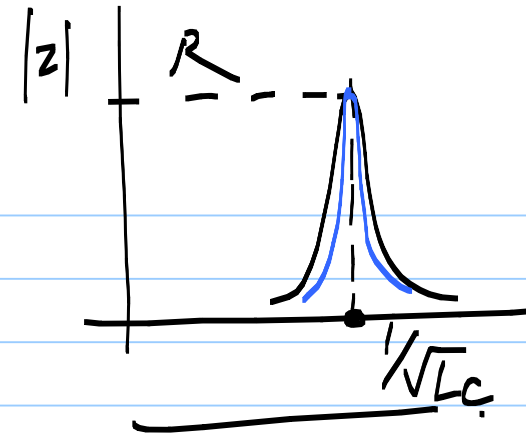


$$g_m > G_p = \frac{1}{R}$$

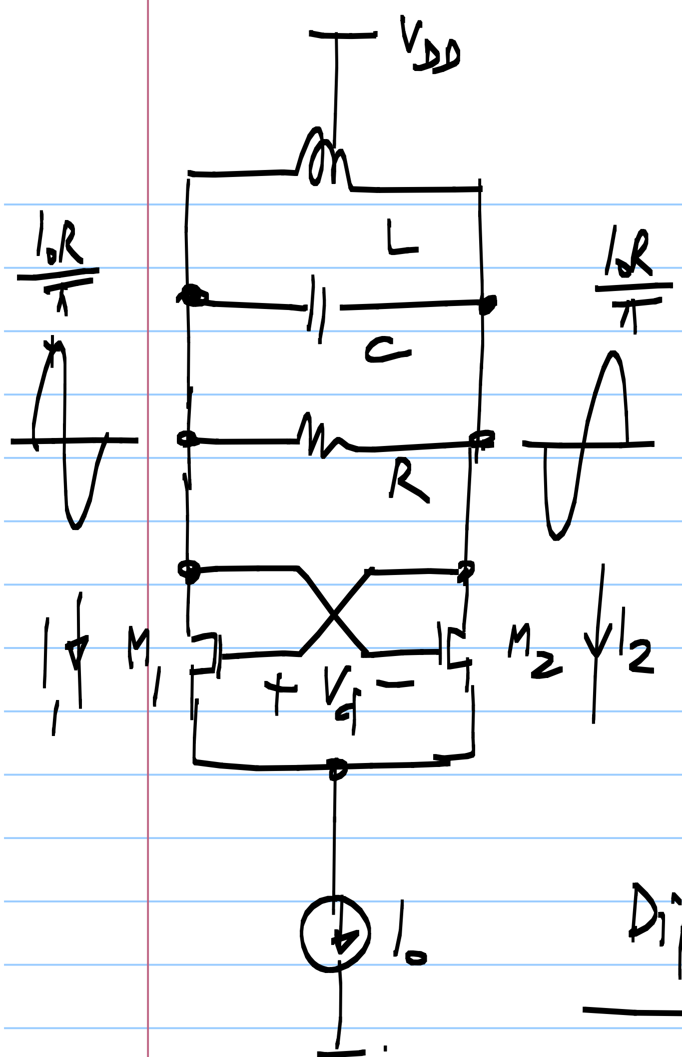
For reliable startup

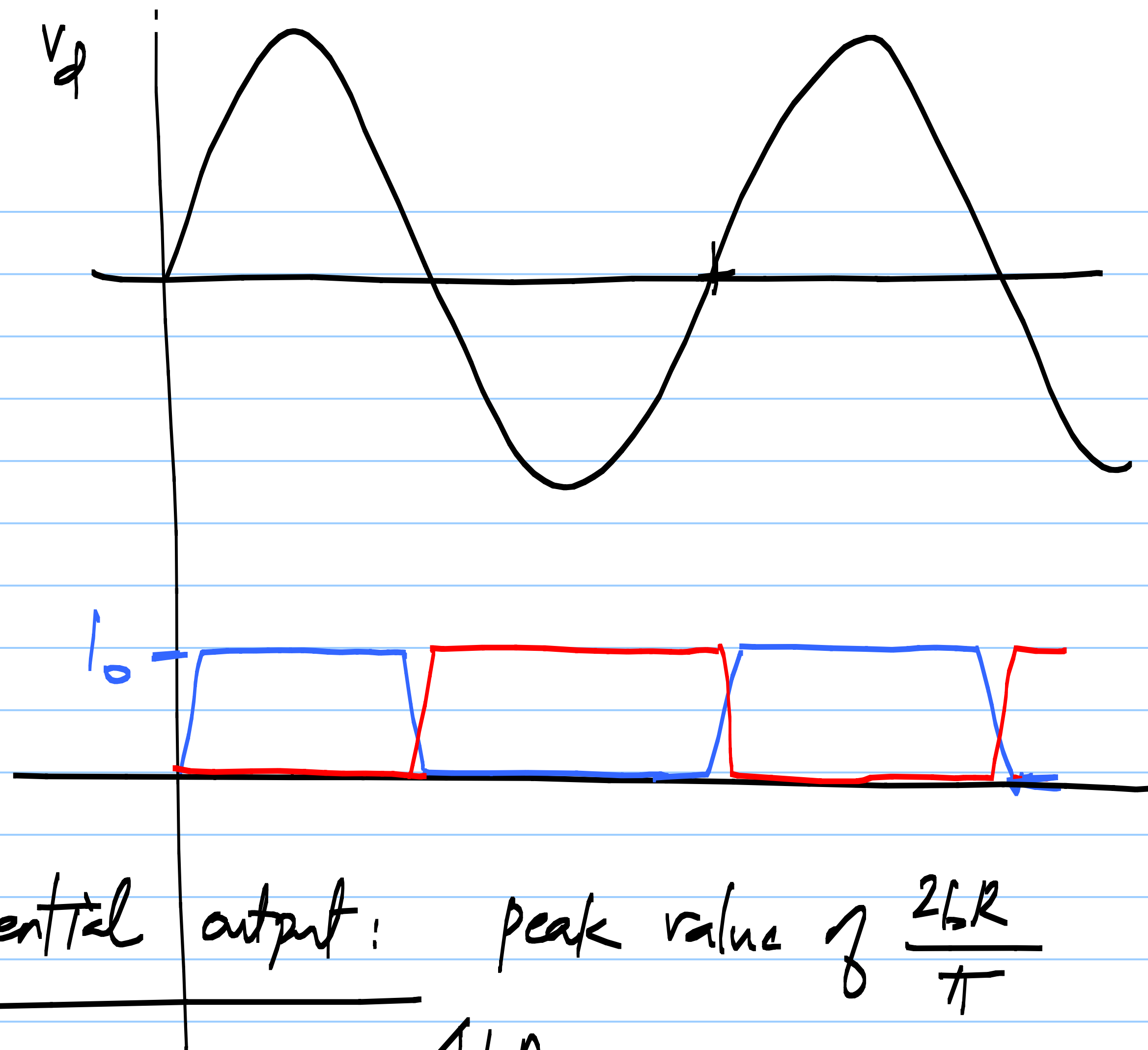






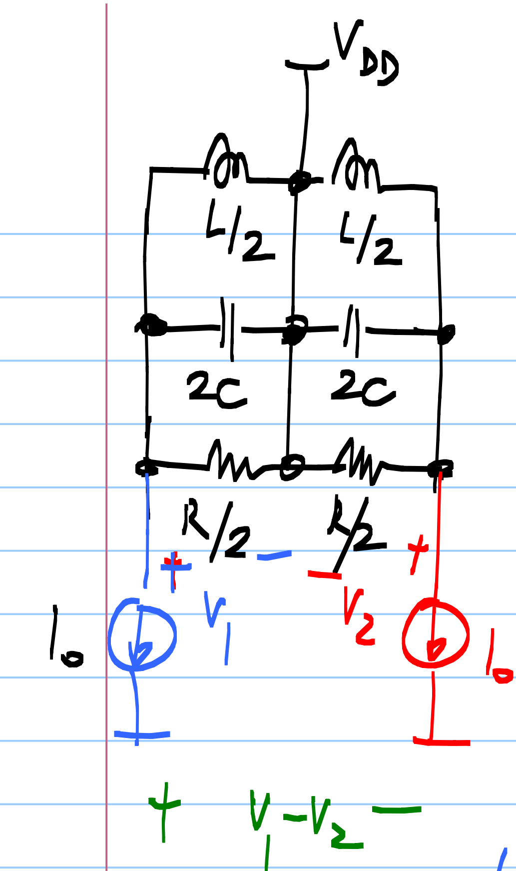
Cross coupled pair





Differential output: peak value of $\frac{2I_0R}{\pi}$

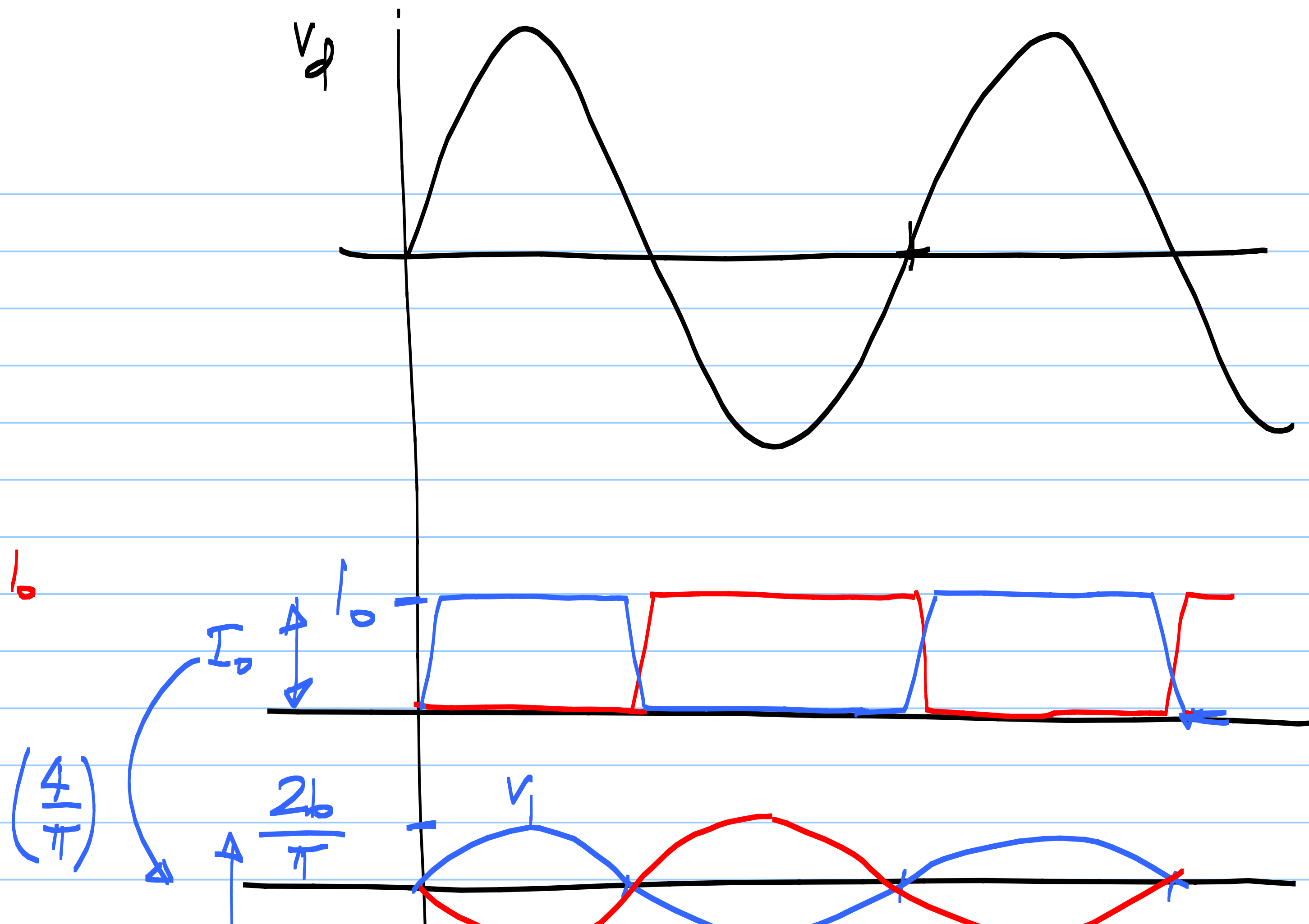
$\frac{4I_0R}{\pi}$ Volts p-p



Amplitude of

$v_1 : \frac{2I_0}{\pi} \cdot R/2$

$v_2 : 2I_0/\pi \cdot R/2$



$v_1 - v_2 : \frac{2 I_0 R}{\pi}$

Cross coupled pair LC oscillator:

* L, C for the desired frequency

$$f_0 = \frac{1}{2\pi\sqrt{LC}};$$

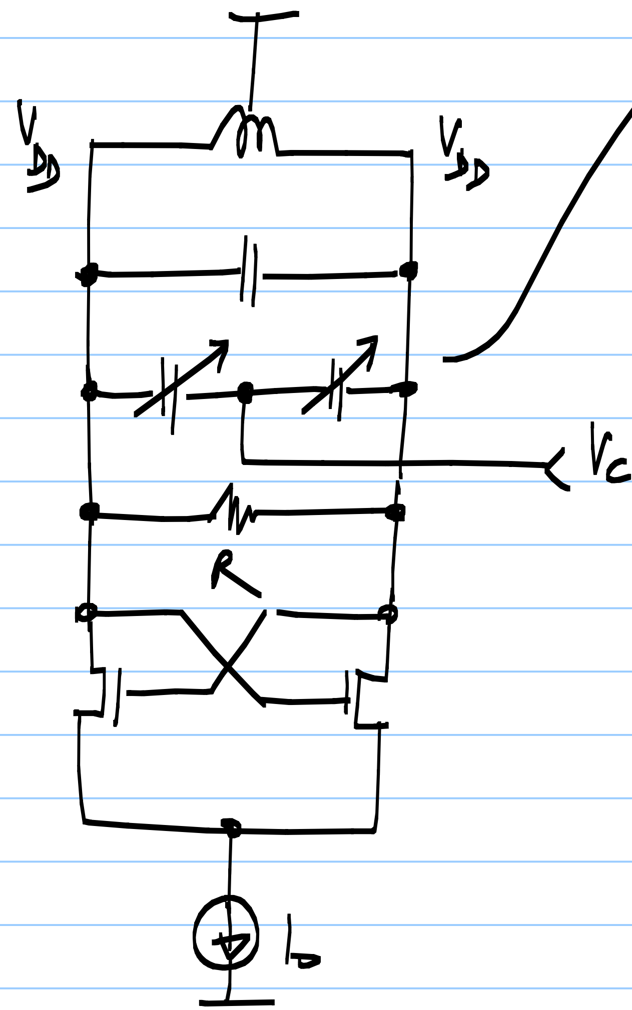
L, C chosen based on

- Quality factor,
- Area

* $\text{Amplitude} = \frac{4 I_0 R}{\pi} \cdot V_{pp} \longrightarrow I_0$

* $g_m > G_p \longrightarrow W/L$

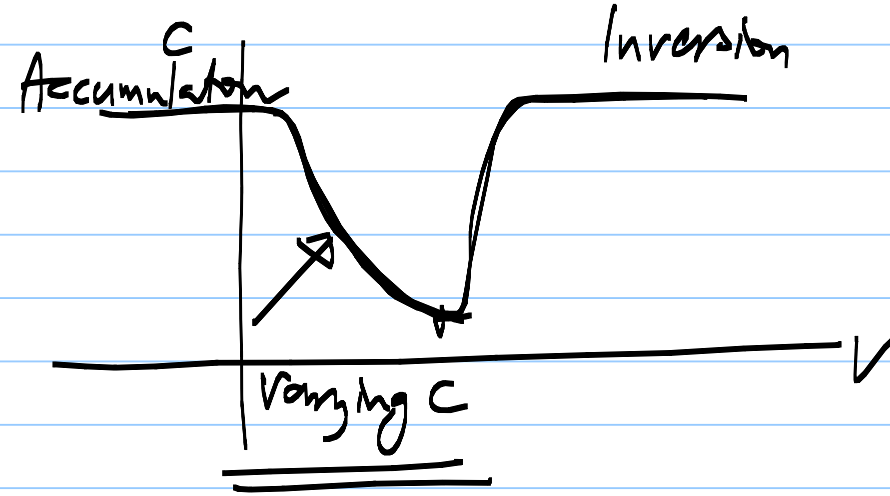
LC VCO:



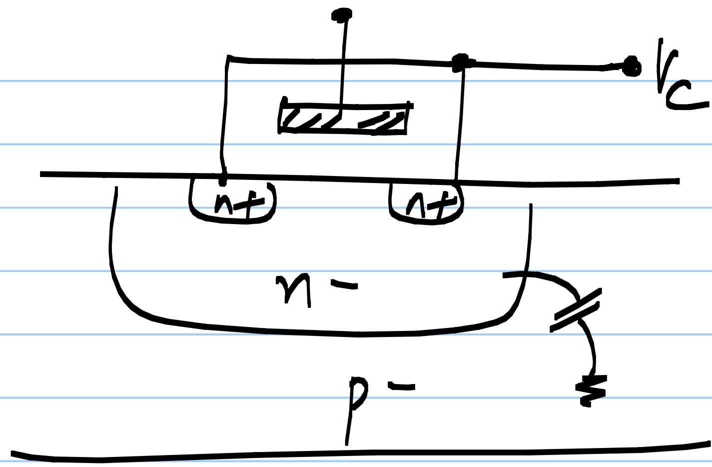
variable capacitors (varactors)

- reverse biased p-n junctions

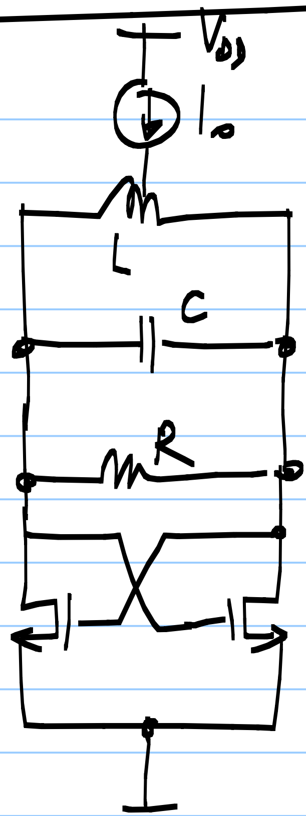
- MOS transistors

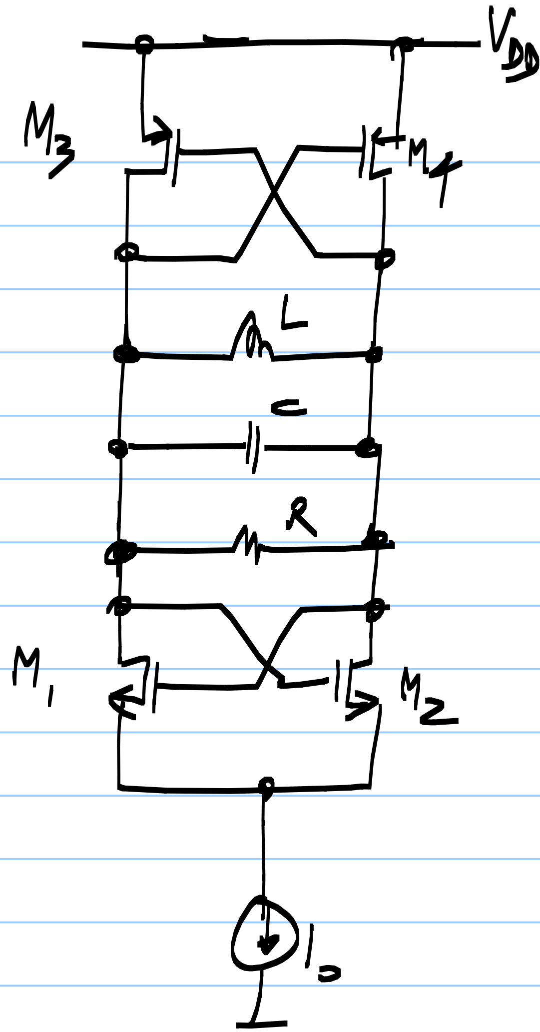


nMOS in an n-Well



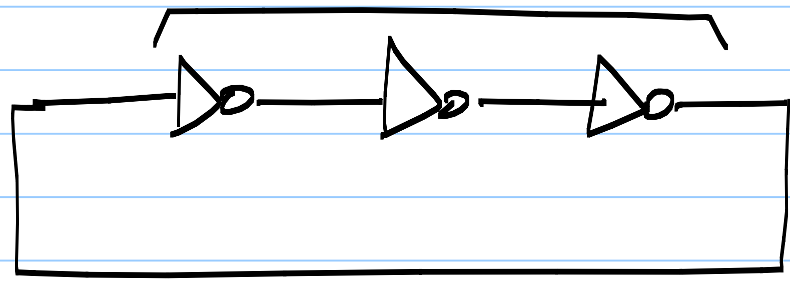
Other variants:





Ring oscillators:

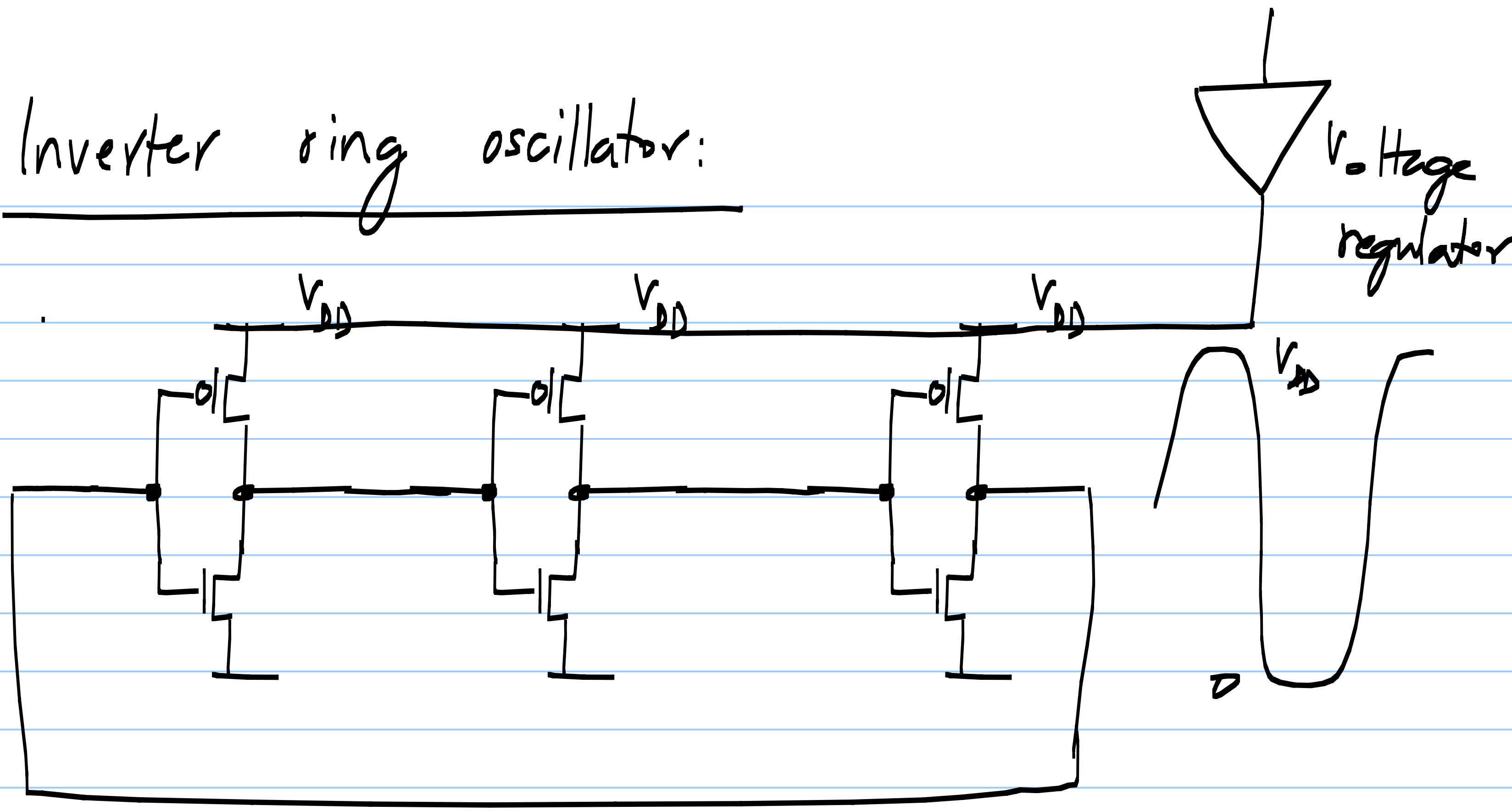
odd # inverters



Osc. period = $2 \cdot N \cdot t_d$

inverter delay

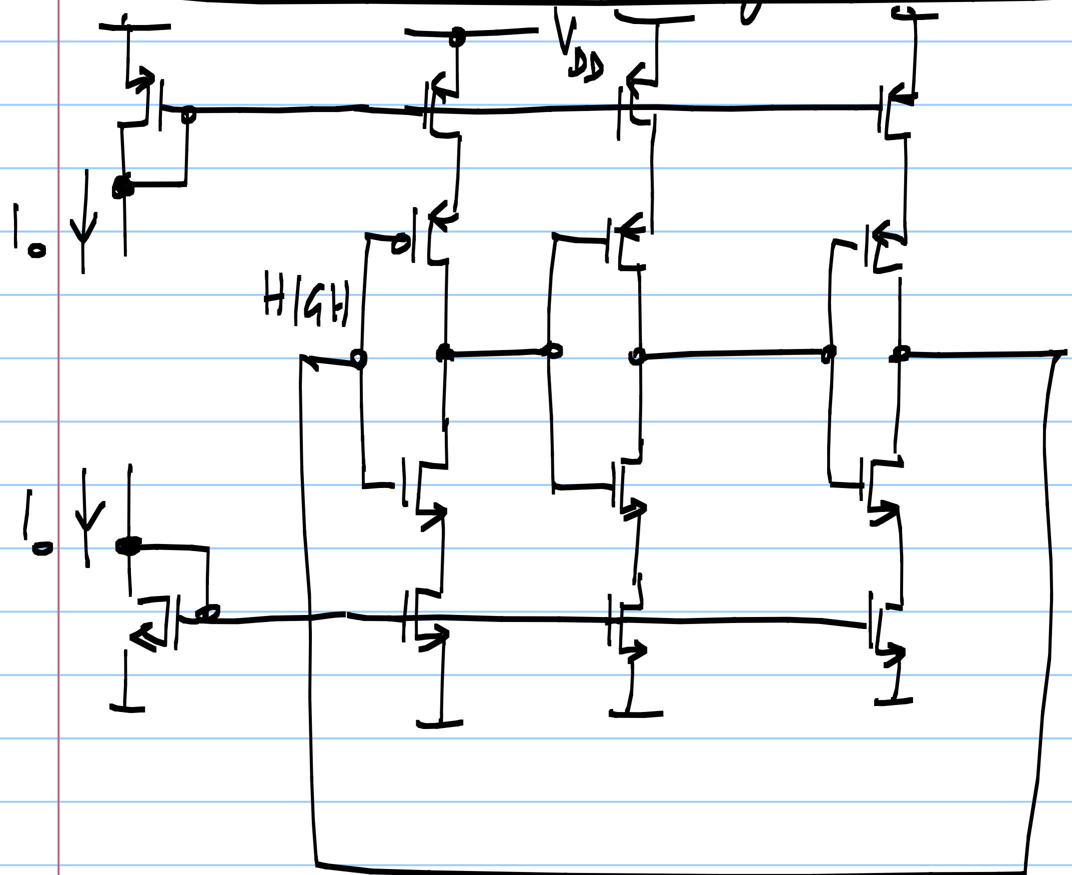
Inverter ring oscillator:



Osc. freq. ↑ with reducing L

Phase noise ↑ with reducing L

Current starved ring oscillator:



* Better (lower) sensitivity to the power supply

* I_o controls the frequency.

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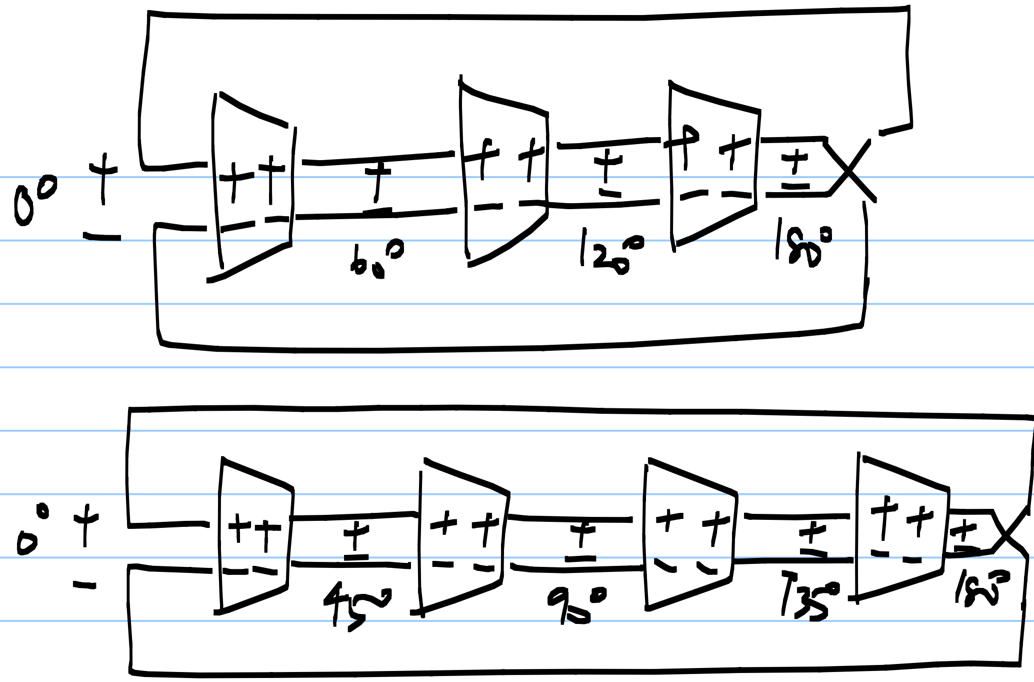
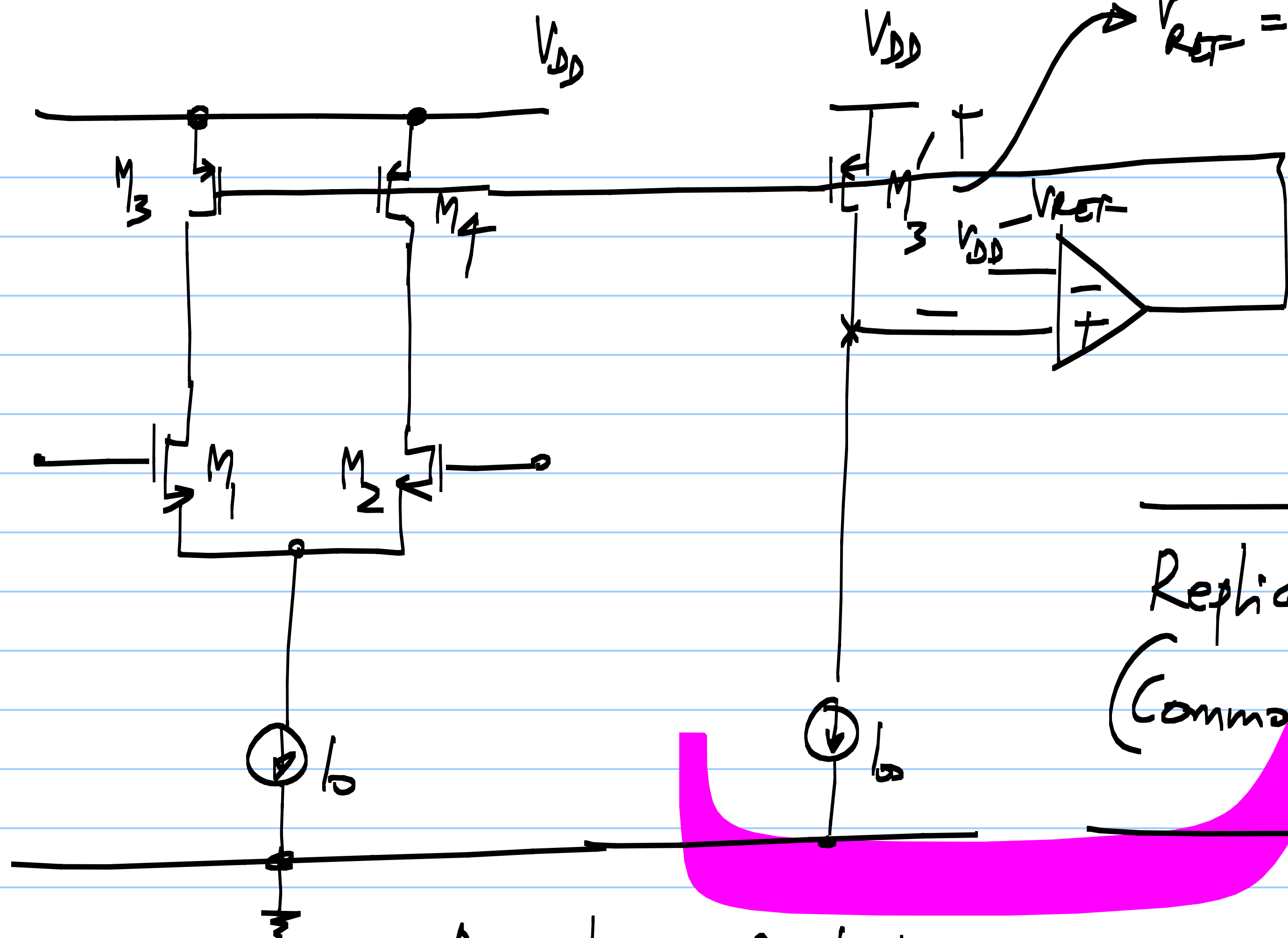


Can generate quadrature waveforms

$V_{REF} = R_{M3'} I_0$



Replica biasing (Common to all cells)

$R_{3,4} \cdot I_0 = \text{constant}$

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LC oscillators:

* Low phase noise [Reduces with increasing Q]
* Limited tuning range

Ring oscillators

* Higher phase noise
* Wider tuning range