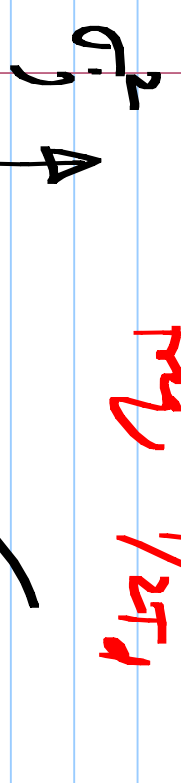
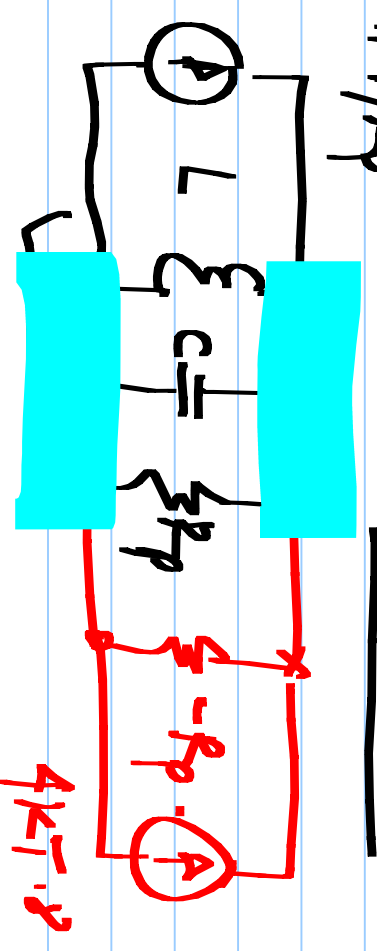
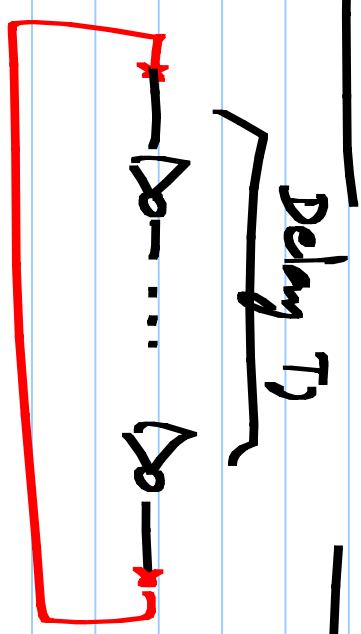


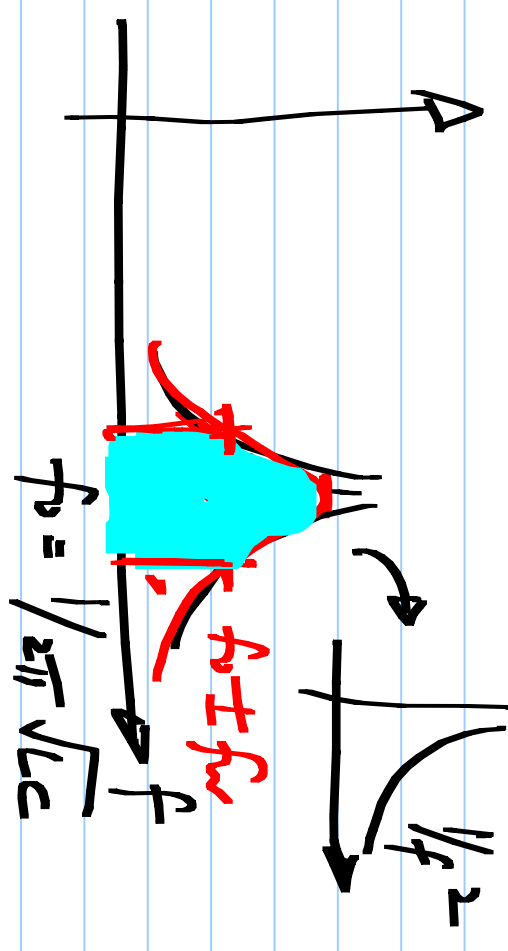
ECE 6322 (w/ inversion) VCOs

4kT/Rp

7/3/2018



Lossy LC tank



$\Delta S \propto R_p$

$1/f^2$

$$S_{\phi}(f) = \frac{A}{f^2}$$

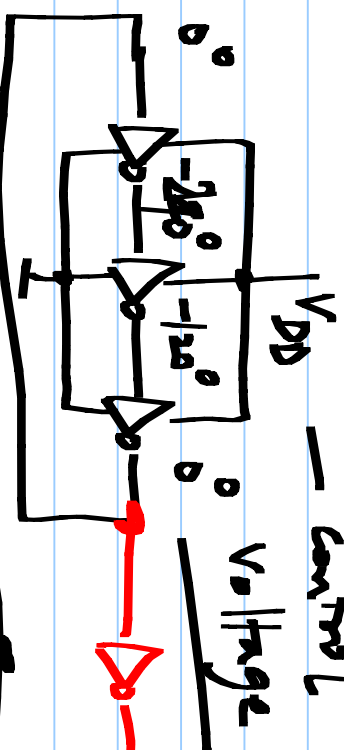
Double-sided PSD

$$\mathcal{L}(f) = \frac{A}{f^2} \quad f > 0 \quad \text{Jitter!}$$

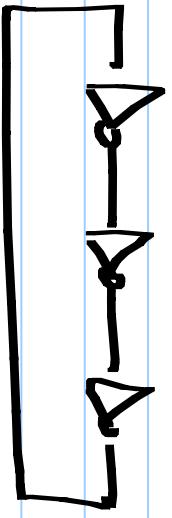
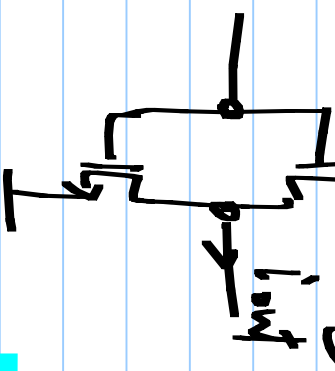
$$S_{\nu}(f) = \frac{V_p^2}{2\pi f_w \left( 1 + \left( \frac{f - f_w}{f_w} \right)^2 \right)}$$
$$\int_{-\infty}^{\infty} S_{\nu}(f) df = \frac{V_p^2}{2}$$

$$|f - f_w| \gg f_w \quad S_{\nu}(f) \approx \frac{V_p^2}{2} \cdot \frac{f_w}{(f - f_w)^2} = \frac{V_p^2}{2} \cdot \frac{A}{(f - f_w)^2}$$
$$\left[ A = f_w / \pi \right]$$

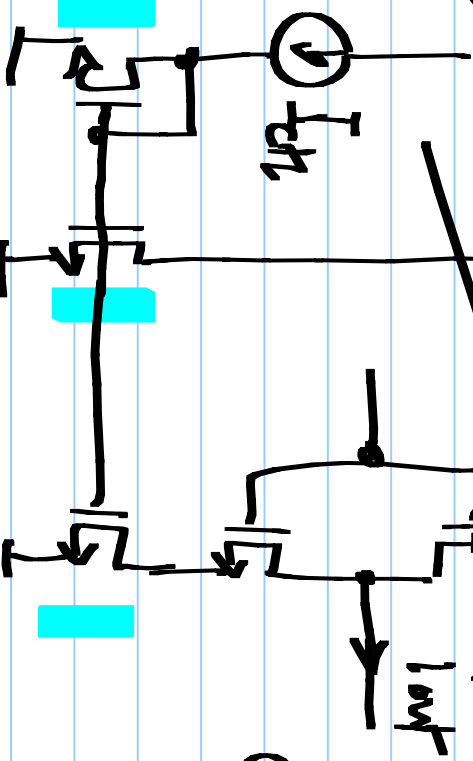
Ring oscillators: + compact, + widely tunable, - poor phase noise



limited by  $V_{DD}$

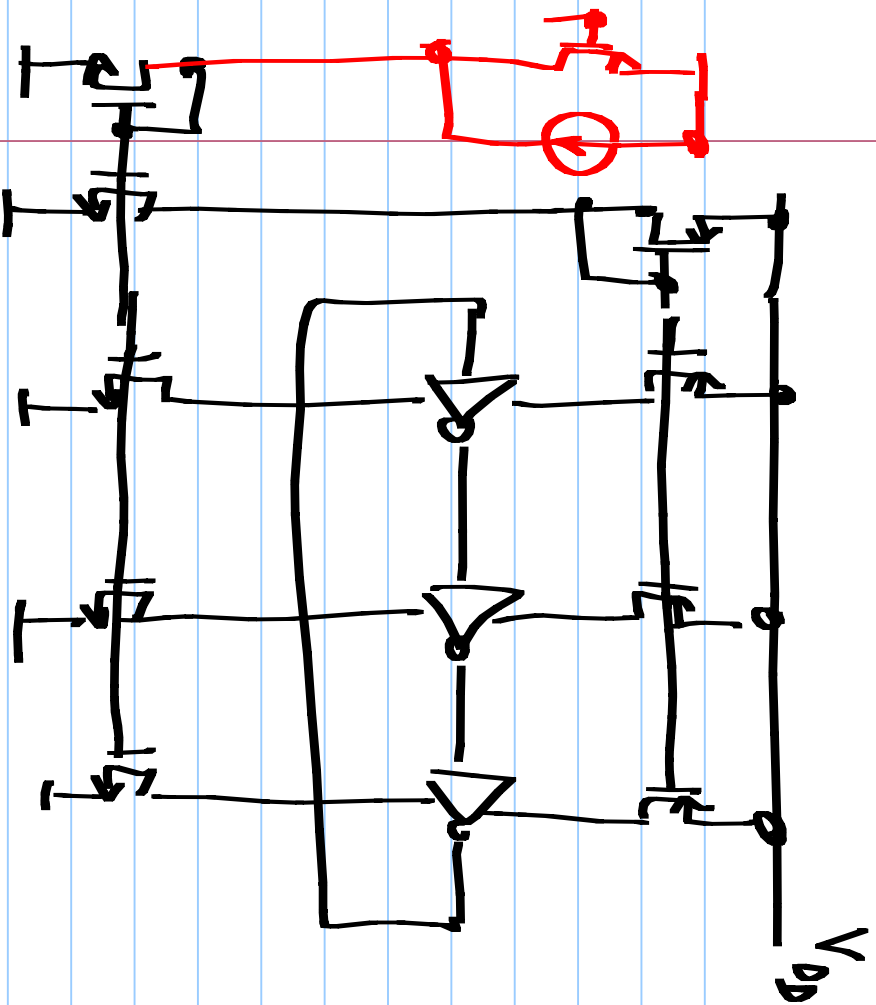


control current

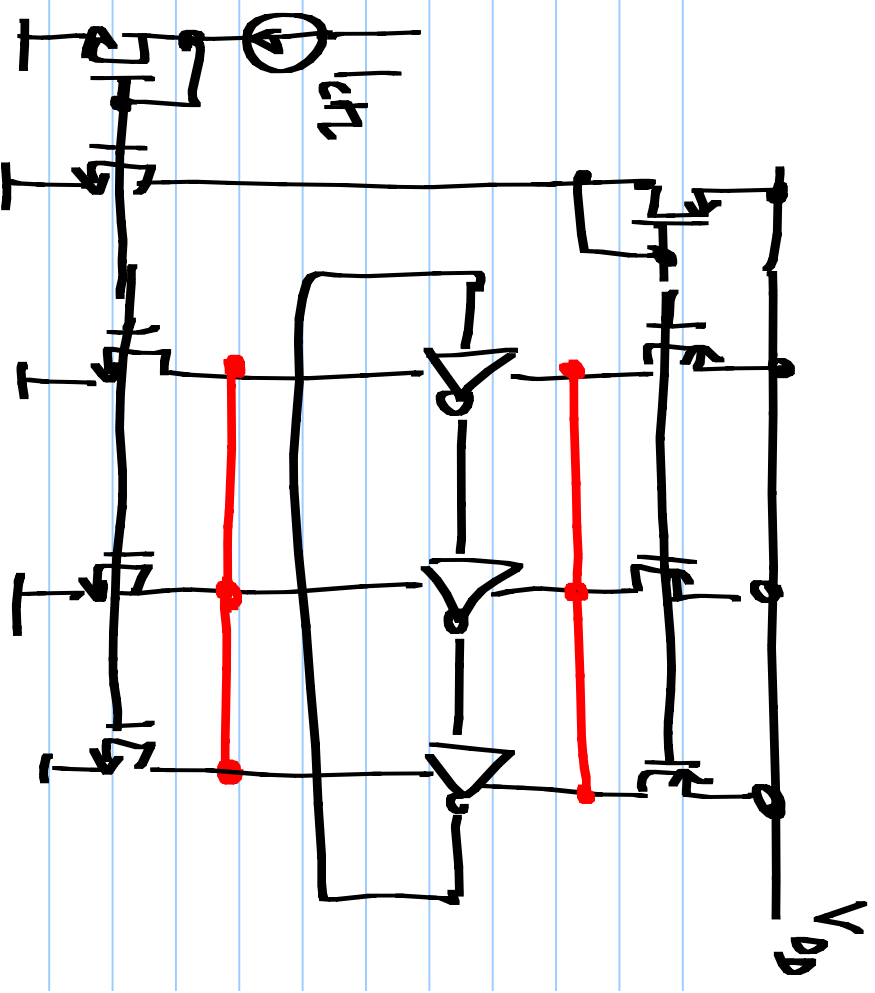


current-starved

inverter

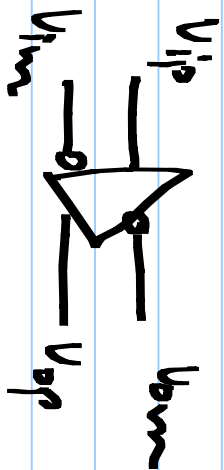


Current starved ring  
oscillator



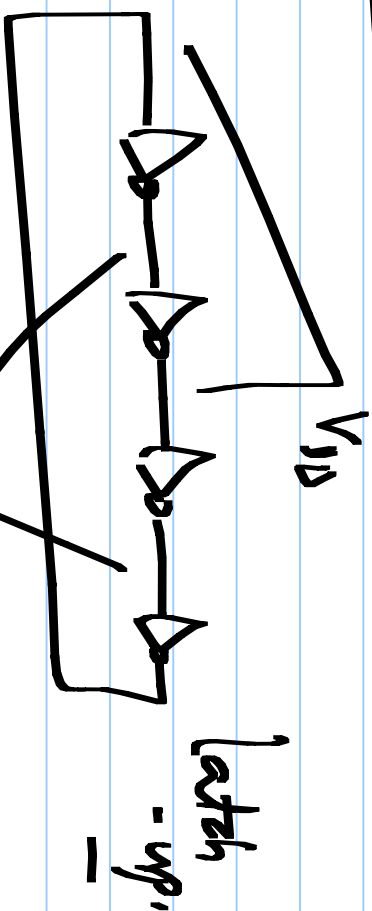
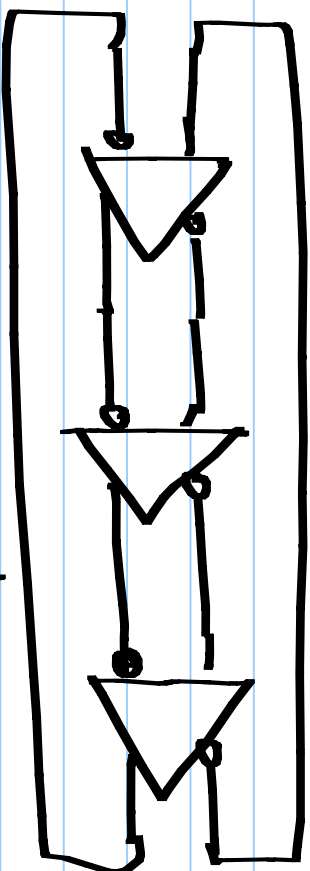
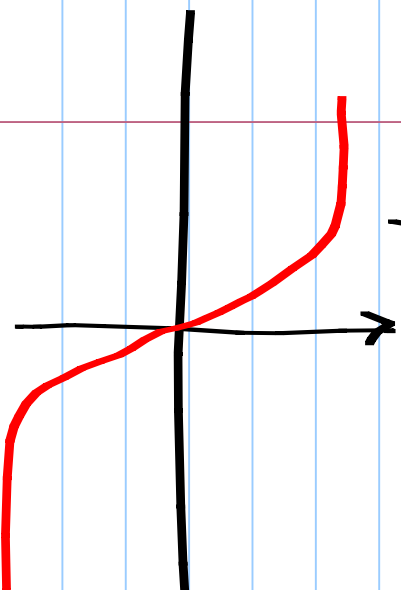
Single-ended oscillator

# Differential oscillator

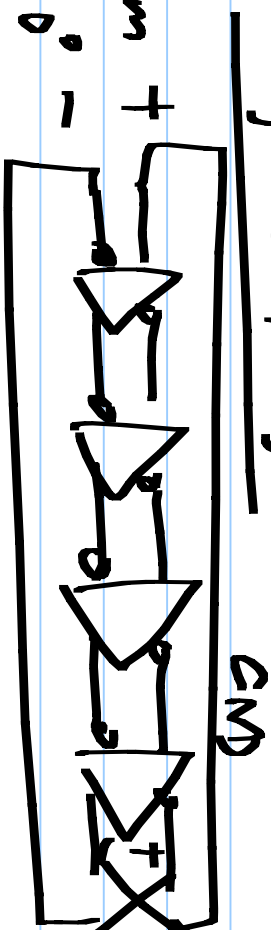


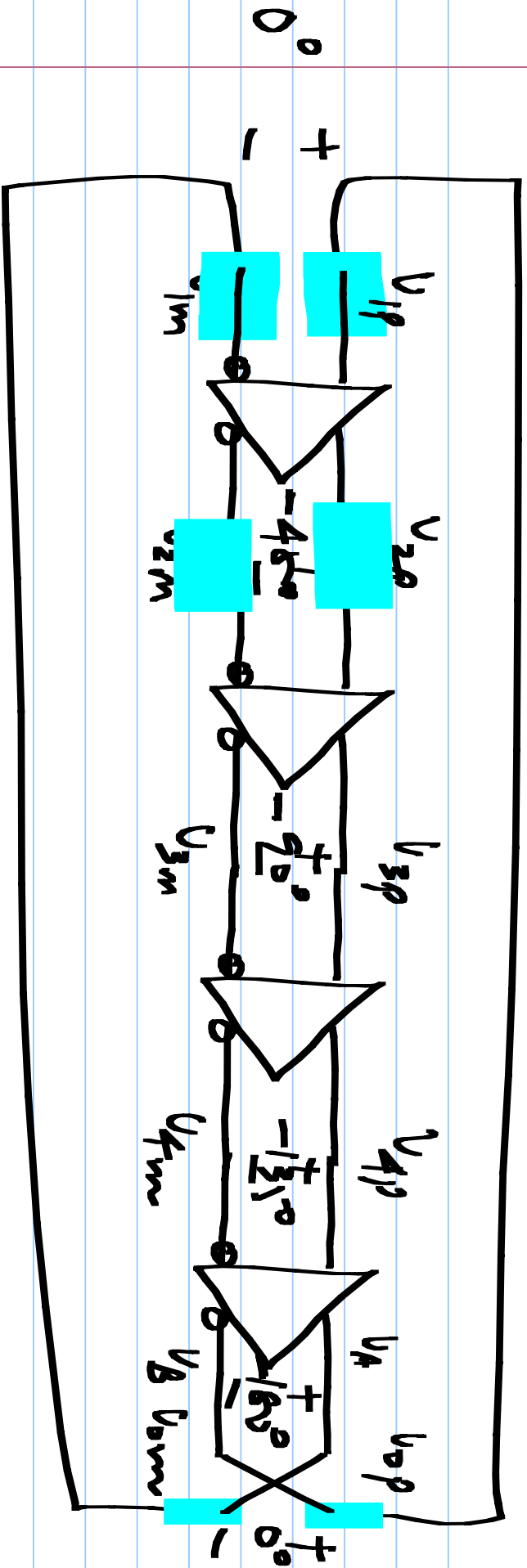
Differential  
inverters

$$v_{sp} - v_{om}$$

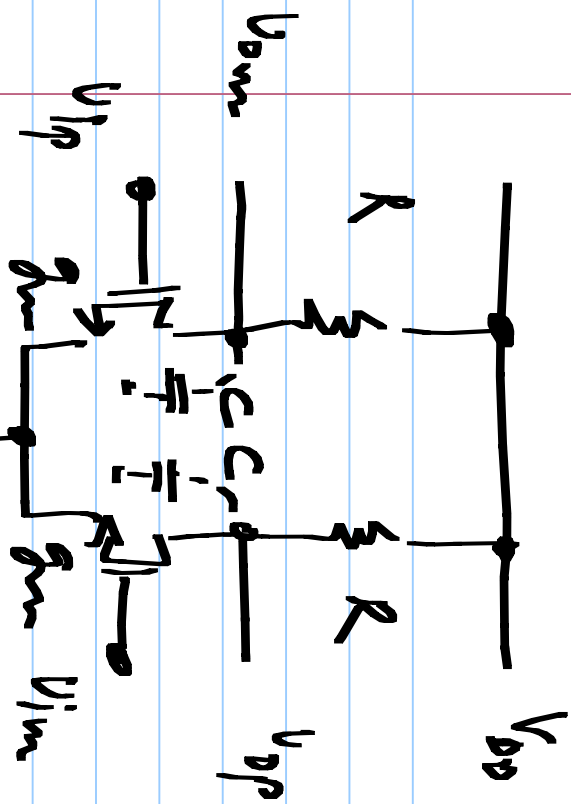


Waveforms 45° apart





$V_{2p} - V_{2m}$  legs  $V_{1p} - V_{1m}$  by  $45^\circ$



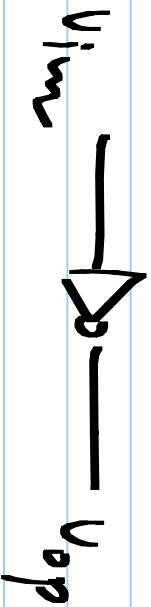
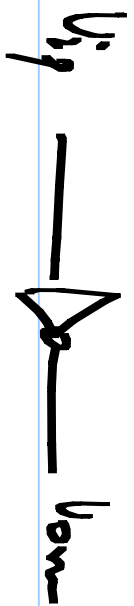
Tuning

Change bias current & R

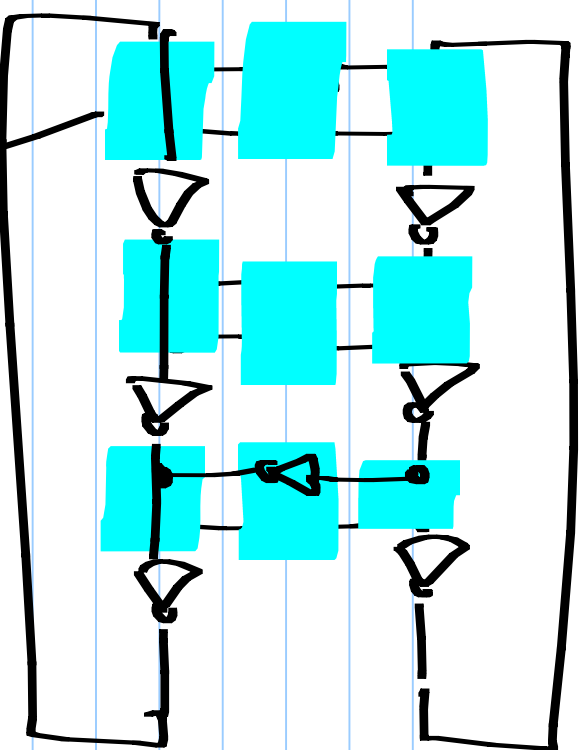
with constant bias R product

$g_m R$ : large

Delay  $\propto R_c$



Pseudo differential structure

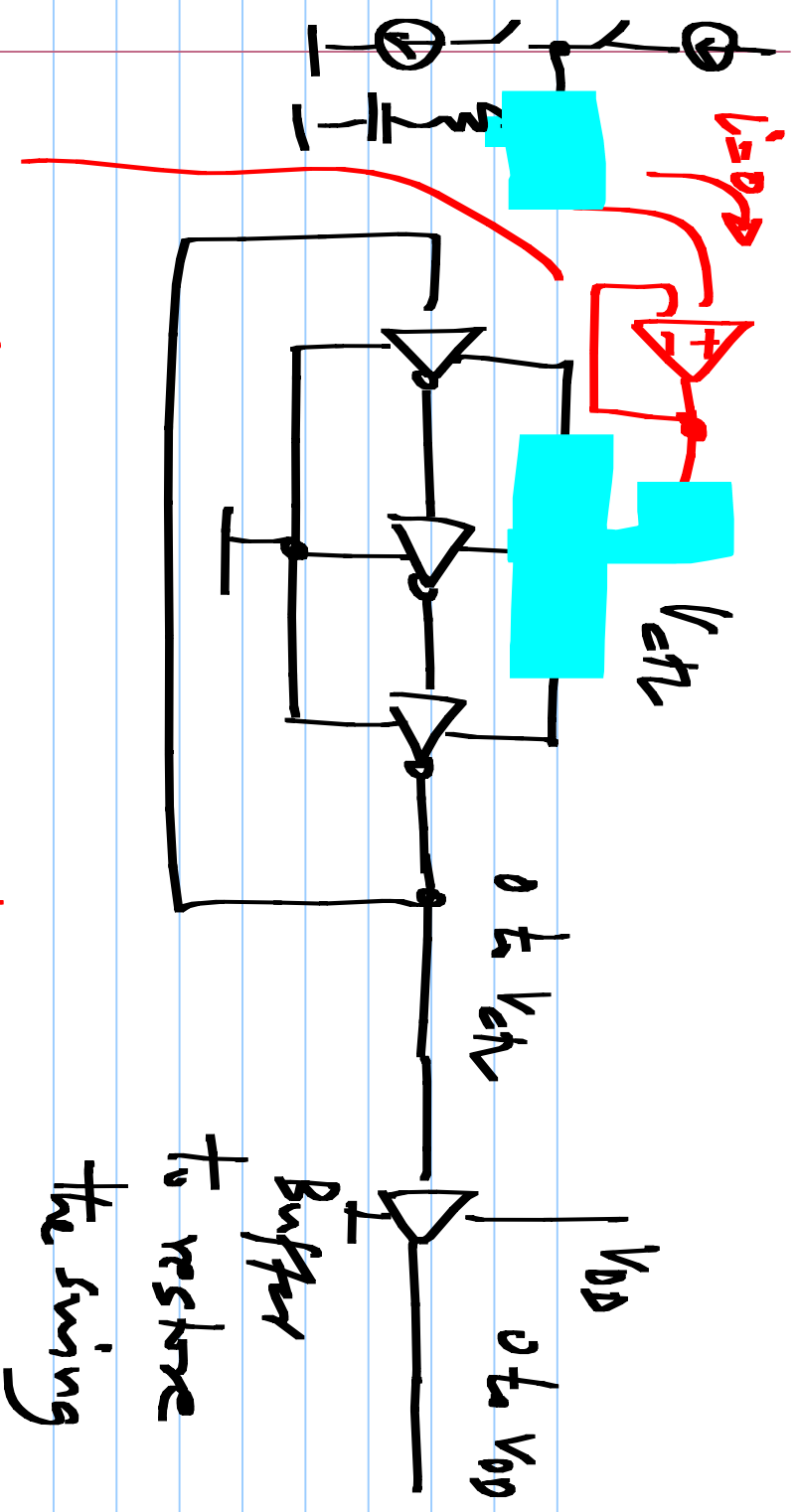


Provides common-mode

rejection

Forces oscillations in diff mode





To supply oscillator's current

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Buffer  
to restore  
the swing

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