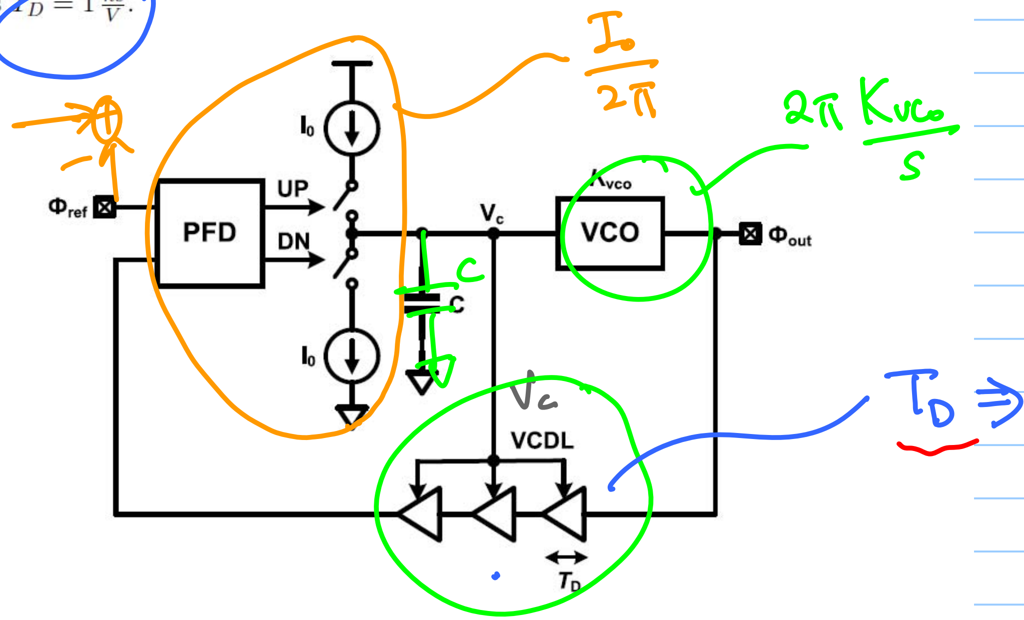
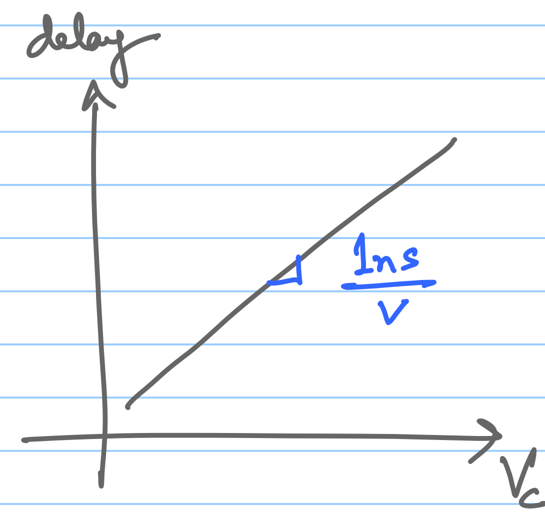
ECE 504 - Lecture 19

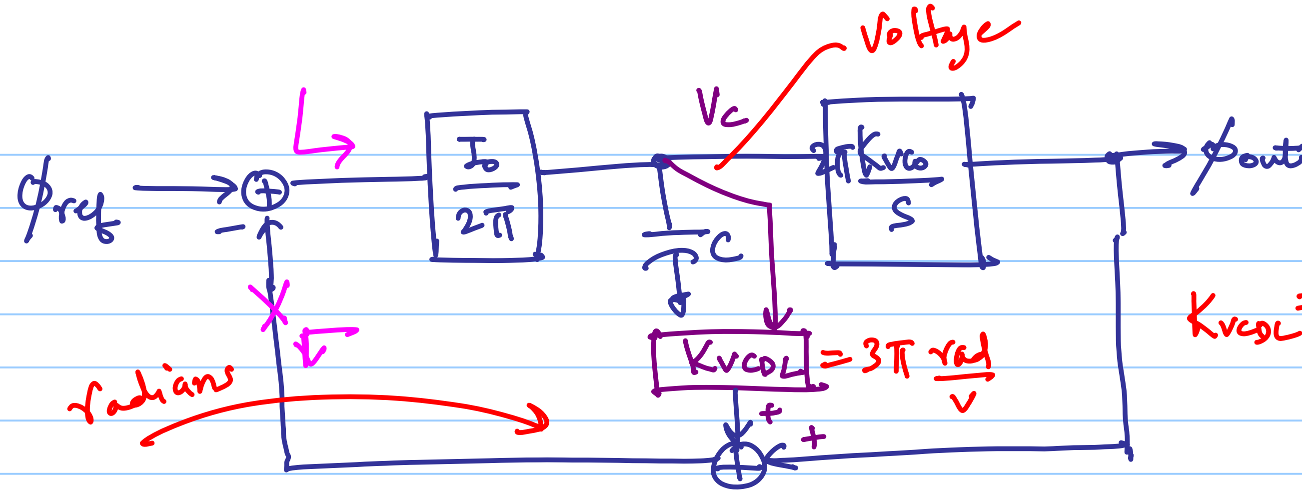
Note Title 10/26/2016

1. Consider an alternative PLL design shown below. Here, $K_{VCO} = 150\,\frac{MHz}{V}$, $I_0 = 100\mu A$, frequencies $f_{in} = f_{out} = 500$ MHz, and the delay of each of the elements in the VCDL is given as $T_D = 1\,\frac{ns}{V}$.



$T_D \Rightarrow \frac{1\,ns}{V}$





$$K_{VCDL} = 3T_D \times \frac{2\pi}{T_{ck}} \ \text{rad/V}$$

$$= 6\pi \cdot f_{ref} \cdot T_D$$

$$= 3\pi \frac{\text{rad}}{V}$$

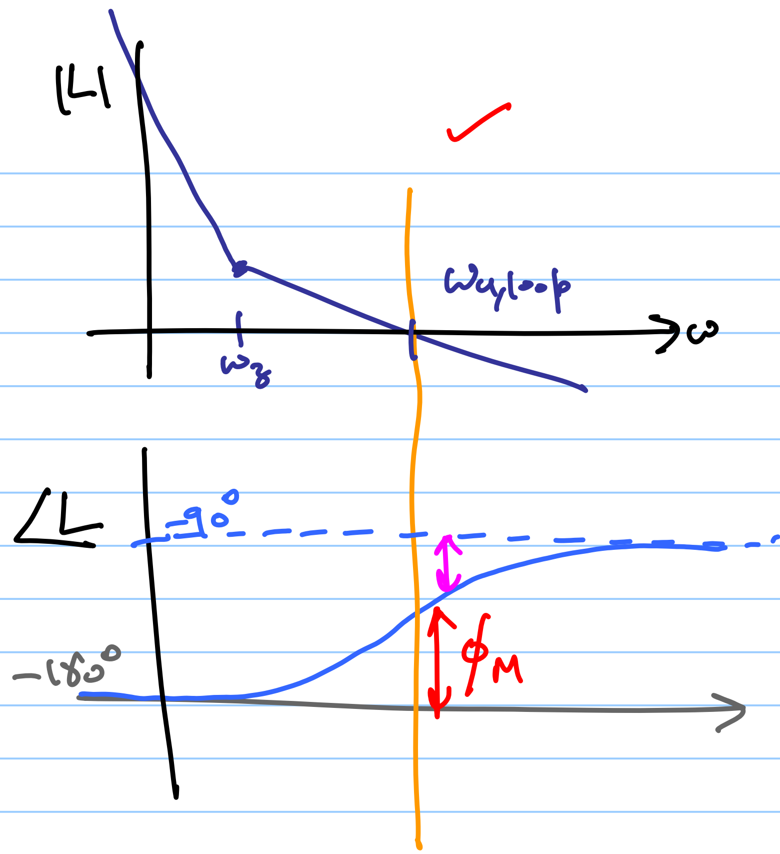
integral, prop path

$$L(s) = \frac{I_o}{2\pi s C}\left(\frac{2\pi K_{vco}}{s} + K_{VCDL}\right)$$

$$= \frac{I_o}{2\pi s^2 C}\left[2\pi K_{vco} + s K_{VCDL}\right] \rightarrow (1)$$

$$\omega_z = \frac{2\pi K_{vco}}{K_{VCDL}}$$

$$\omega_z = \frac{1}{RC}$$



Type-II, 2nd order system

$$\phi_M = \tan^{-1}\left(\frac{\omega_{u,loop}}{\omega_z}\right) = 45^\circ$$

$$\omega_{u,loop} = \omega_z \cdot \tan(45^\circ)$$

$$L(s) = \frac{2\pi I_0 K_{vco}}{2\pi C s^2}\left[1 + \frac{s K_{vco} L}{2\pi K_{vco}}\right]$$

~~$\omega_{u,loop} \gg \omega_z$~~

$$|L(j\omega_{u,loop})| = 1$$

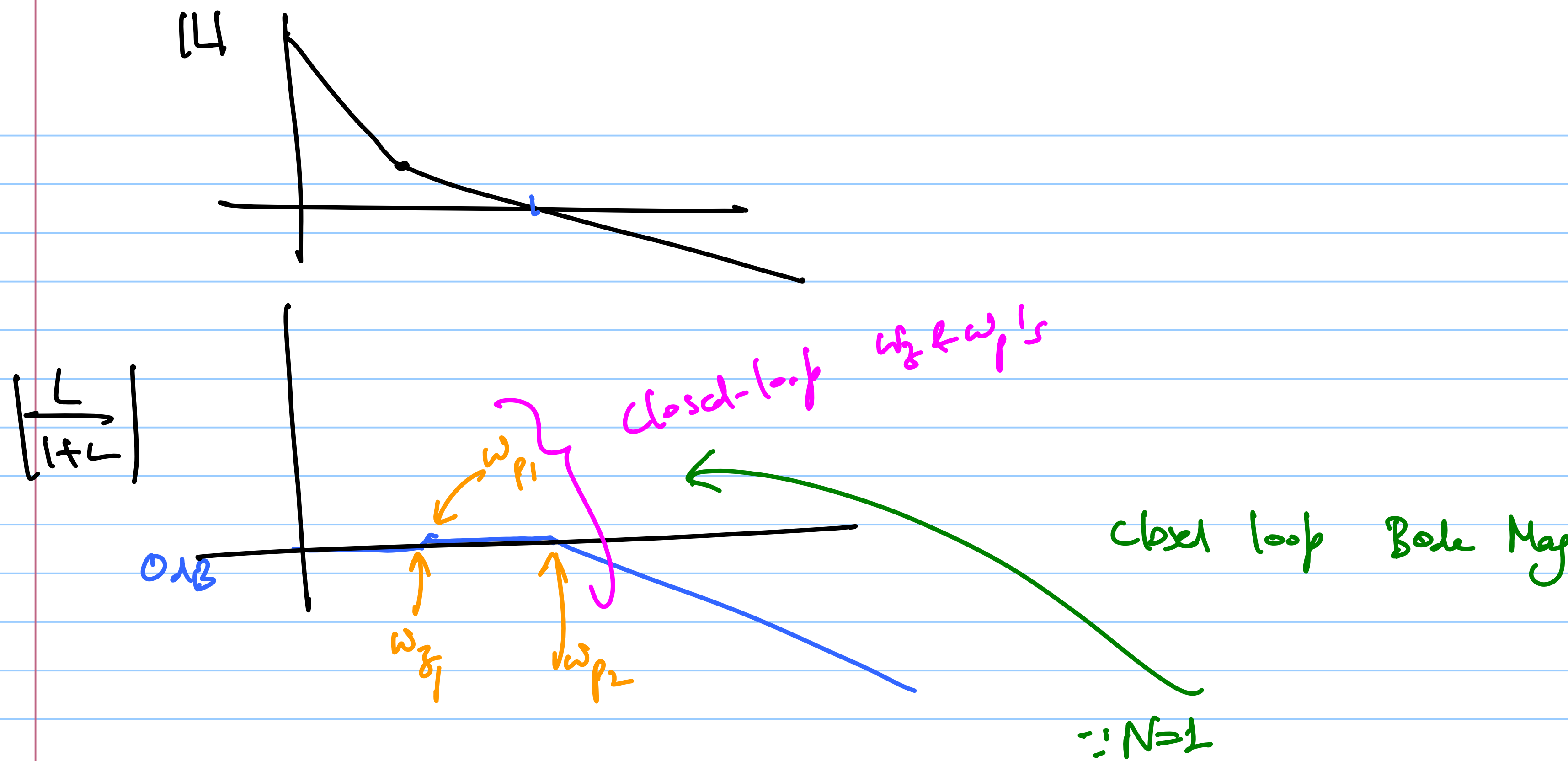
$\omega_{u, \text{c-l}} = \omega_g$

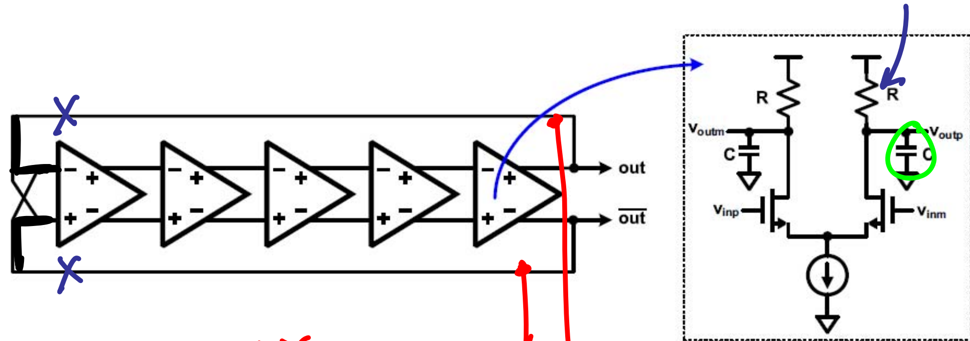
↳ $c = ?$

(d) $H_{cl}(s) = \frac{\phi_{out}}{\phi_{ry}}(s) = \frac{G(s)}{1 + L(s)}$ $\because N = 1$

$= \frac{L(s)}{1 + L(s)}$ ← plug-in $L(s)$

(e)


|L|
|L/(1+L)|
0dB
closed-loop ω_z & ω_p's
ω_{p1}
ω_{z1}
ω_{p2}
Closed loop Bode Mag
$\therefore$ N=1



(a) (10 points) Find the frequency of oscillation ω_{osc} if $R = 1\,k\Omega$ and $C = 100\,fF$.

VCO Buffer

$$H(s) = \frac{A_0}{(1 + s/\omega_0)}$$

$$\omega_0 = \frac{1}{RC}$$

$$A_0 = g_m R$$

$$L(s) = \frac{A_0^5}{(1 + s/\omega_0)^5}, \quad \angle L(j\omega) = -5\tan^{-1}\left(\frac{\omega}{\omega_0}\right)$$

$$|\angle L(j\omega)| = 180^\circ$$

$$\tan^{-1}\left(\frac{\omega_{osc}}{\omega_0}\right) = \frac{180^\circ}{5} \Rightarrow \omega_{osc} = \omega_0 \tan(36^\circ)$$

$$= 7.265 \text{ Grad/s}$$

By Barkhausen criterion $= 1.156$ GHz

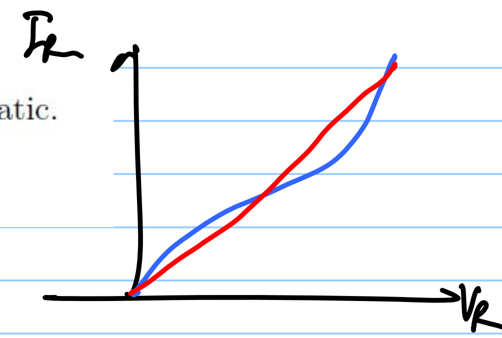
(b) $|L(j\omega_{osc})| = 1$

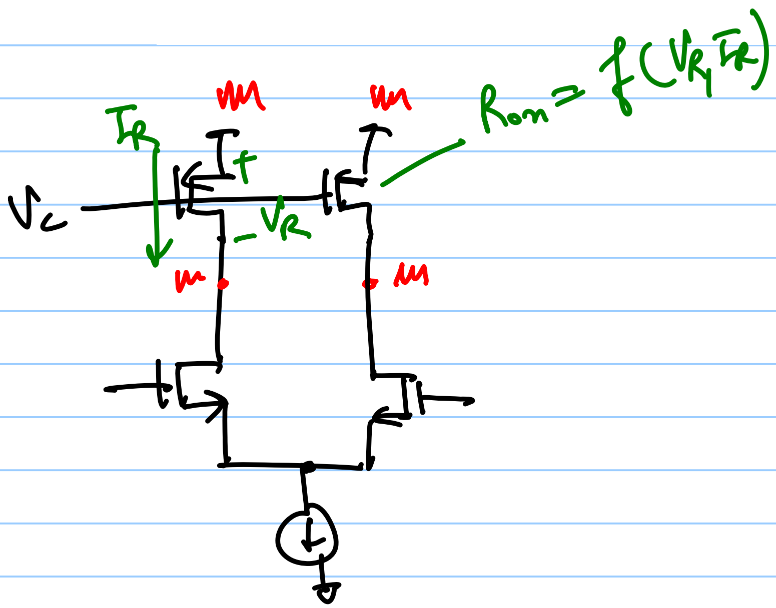
$$\left| \frac{g_m R}{\sqrt{1+\left(\frac{\omega_{osc}}{\omega_0}\right)^2}} \right|^5 = 1 \Rightarrow \frac{g_m R}{\sqrt{1+\tan^2 36^\circ}} = 1$$

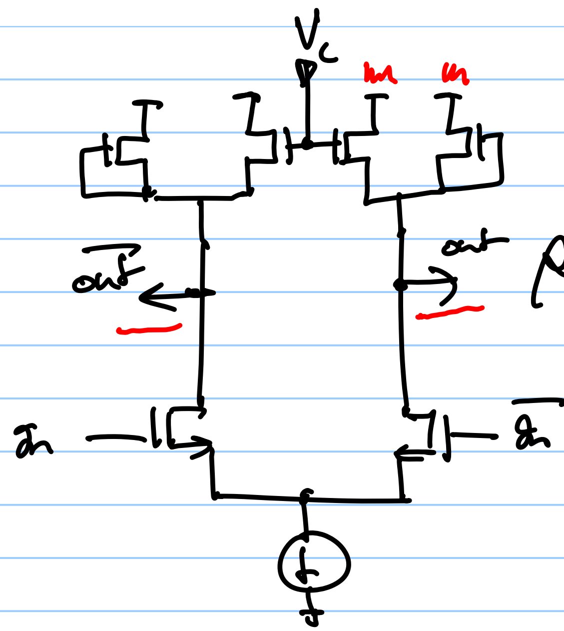
$g_m \triangleq 2\,\frac{mA}{V}$

$g_m = ? = 1.236\,\frac{mA}{V}$

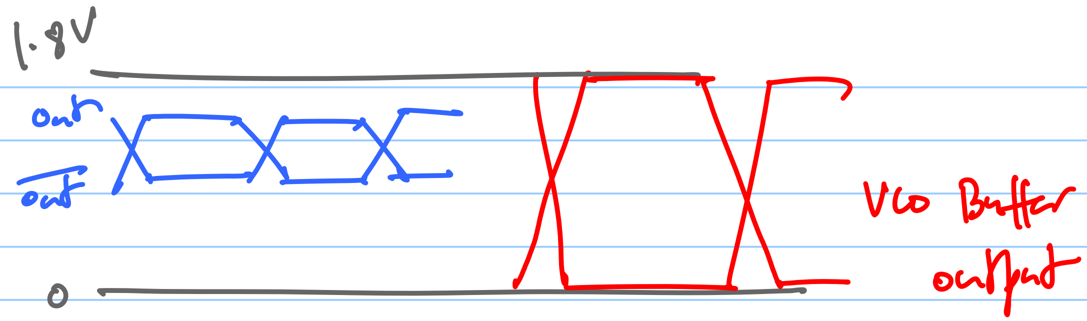
(c) (10 points) A 5-stage VCO needs to be designed based upon the above schematic. Draw schematic of a delay cell to achieve this with best possible PSRR.



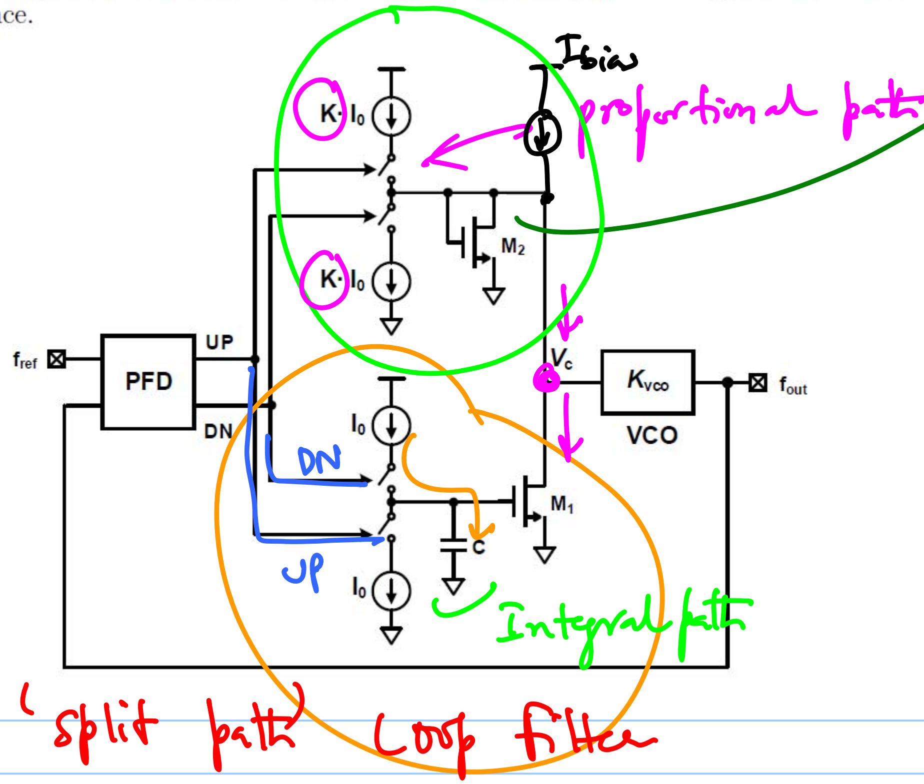


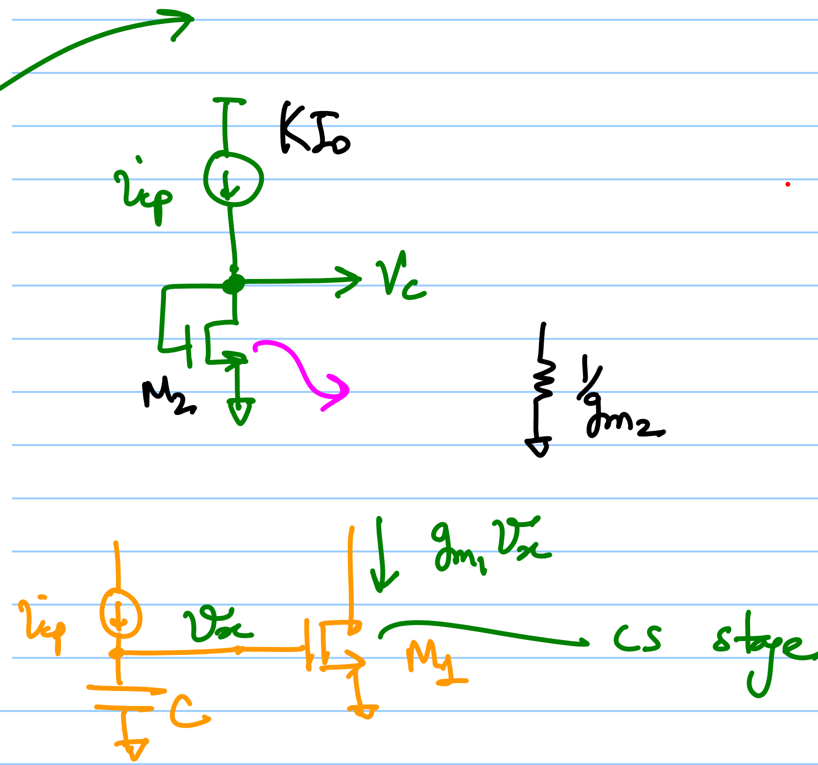


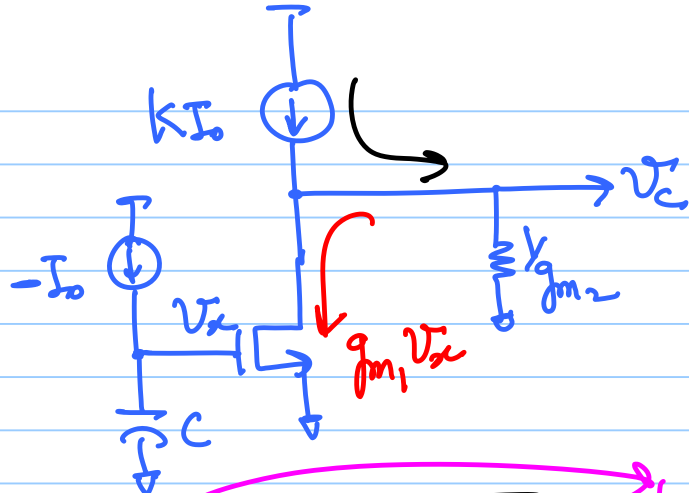
Symmetric delay cell to average out variations in R_{on}


1.8V
out
out
0
VCO Buffer
output

3. In the resistor-less PLL shown below, assume that the VCO gain K_{VCO} is positive, all transistors operate in saturation with output resistance, $r_o = \infty$. Ignore the NMOS capacitance.





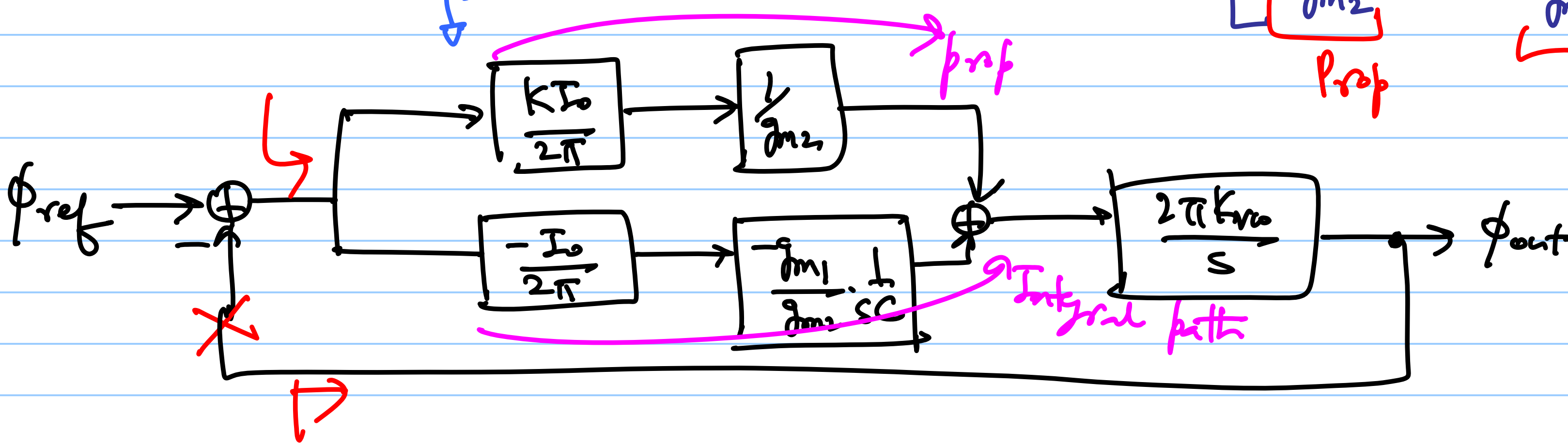


$$v_c = (KI_o - g_{m1} v_x)\frac{1}{g_{m2}}$$

$$= \left[KI_o + g_{m1}\frac{I_o}{sC}\right]\cdot\frac{1}{g_{m2}}$$

$$= \left[\frac{KI_o}{g_{m2}} + \frac{g_{m1}}{g_{m2}}\cdot\frac{I_o}{sC}\right]$$

Prop | Integral



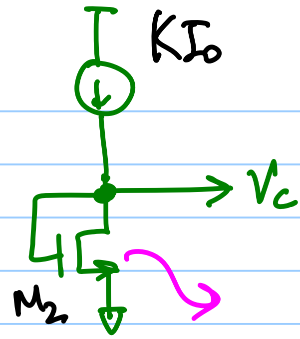
b) $F(s) = \frac{V_c(s)}{I_o} = \frac{K}{g_{m2}} + \left(\frac{g_{m1}}{g_{m2}}\right) \cdot \frac{1}{sC}$

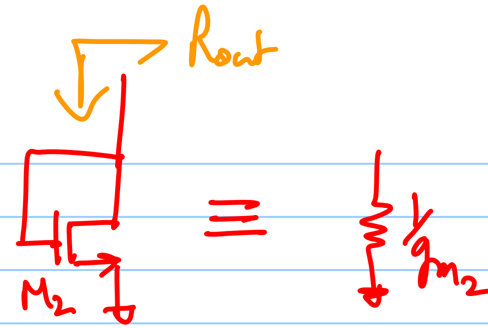
c) $L(s) = \frac{I_o}{2\pi} F(s) \cdot \frac{K_{vco}}{s} \Rightarrow$

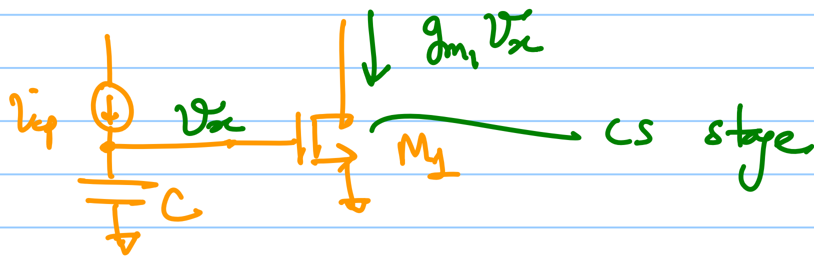
$$\omega_z = \frac{g_{m1}}{KC} \sim \frac{1}{RC}$$

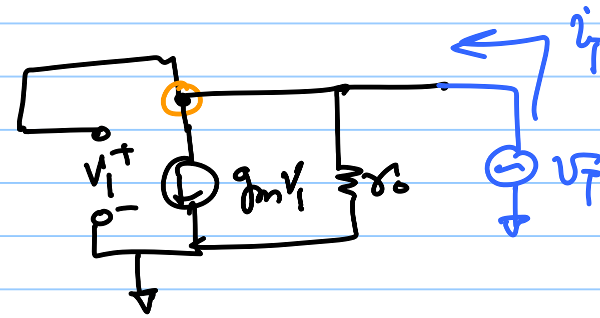
e) Maximizing 'K' helps reduce capacitor area for the same zero location.

d) $H_{cl}(s) \rightarrow$ Same as problem 1





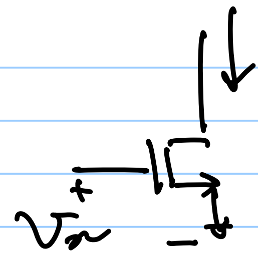




$v_1 = v_T$

KCL $\Rightarrow$ $R_{out} = \frac{v_T}{i_T} = \frac{1}{g_m} \| r_o$

$\simeq 1/g_m$



$i_d = g_m v_x$

C.S.