# ECE 504 - Lecture 14

Note Title 10/10/2016

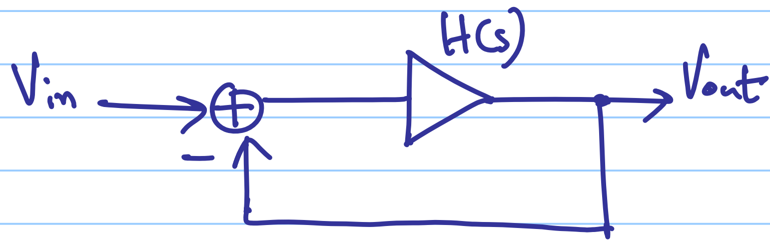
Cadence
↳ Post poll on Piazza
↳ Skype

Midterm Exam
Oct 31, Monday
in class
↳ Closed Book/notes/PC
* Cheat sheet A4 size both sides
* Sample Exam Upload

# Oscillators Basics!

LTI

NL + TV




Loop-gain $L(s) = H(s)$

$\because k = 1$

"Small-signal understanding"

$$\frac{V_{out}}{V_{in}}(s) = \frac{H(s)}{1 + L(s)}$$

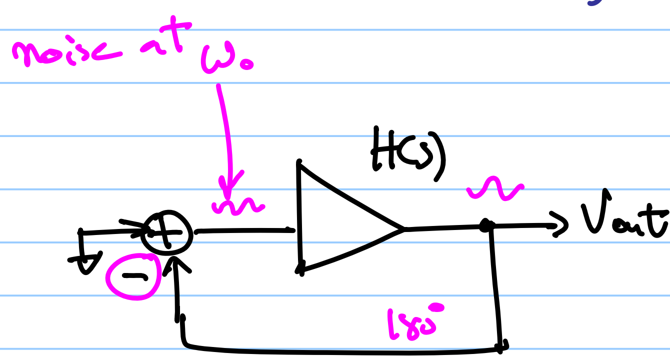
For oscillate at $s = j\omega_0$, we require

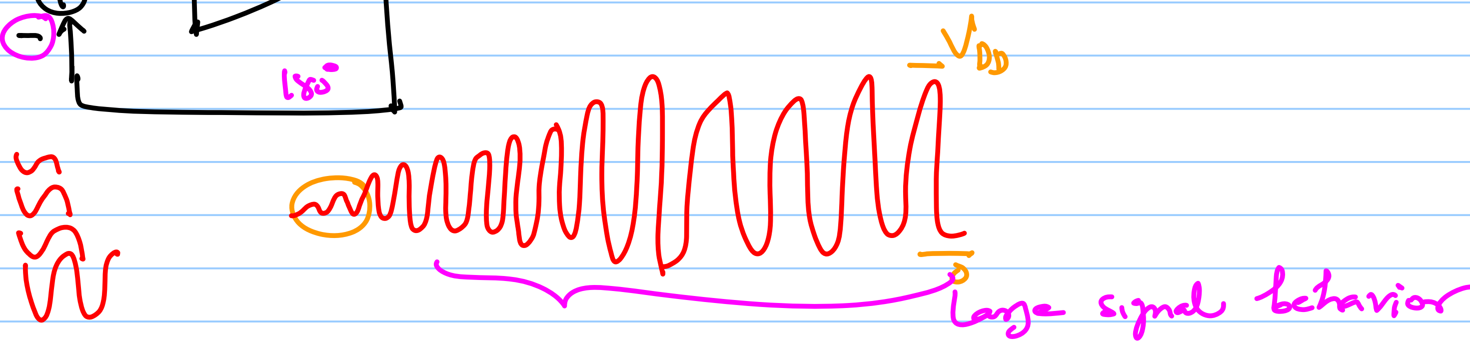
$L(j\omega_0) = -1 \Rightarrow$

$$\Rightarrow \quad |L(j\omega_0)| = 1 \quad \& \quad \angle L(j\omega_0) = -180^\circ$$

in this case

$\Rightarrow$ closed-loop gain $= \infty$

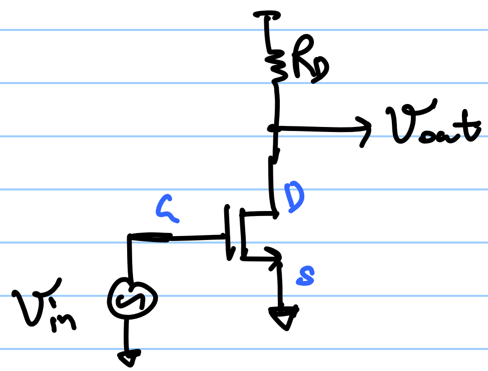


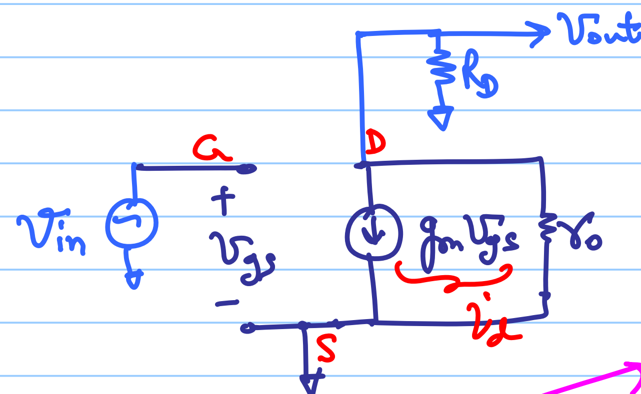
$|L(j\omega_0)| = -1$ is necessary but not sufficient

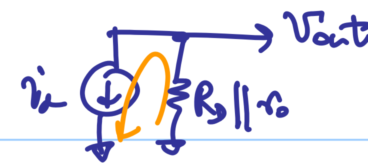
↳ typically we choose the loop gain $|L(j\omega_0)|$ at least 2 or more

# Comm[o]n Source Amp.




Small-signal picture of the amplifier



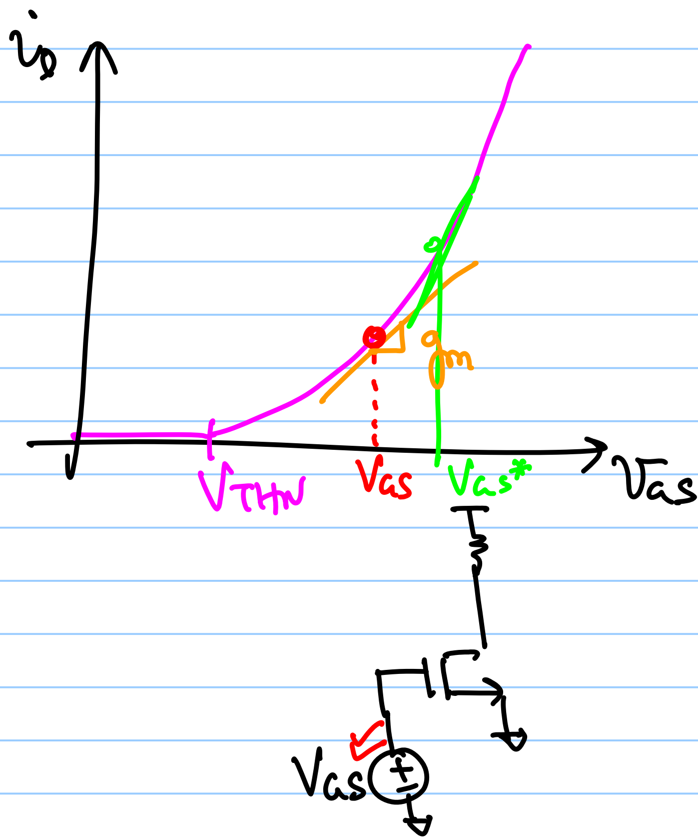

$$i_d + \frac{v_{out}}{R_D||r_o} = 0$$

$$\Rightarrow v_{out} = -i_d(R_D||r_o)$$

$$g_m v_{gs} = g_m v_{in}$$

$$v_{out} = -i_d(r_o||R_D)$$

$$= -g_m(r_o||R_D)\, v_{in}$$




$$A_v = \frac{v_{out}}{v_{in}} = -\, g_m (R_D \| r_o)$$

??

$$\simeq -g_m R_D$$

$R_D \ll r_o$

$g_m$ → trans conductance

$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{\underbrace{v_{GS} = V_{GS}}_{\text{Bias-point}}}$$

$g_m$ sat

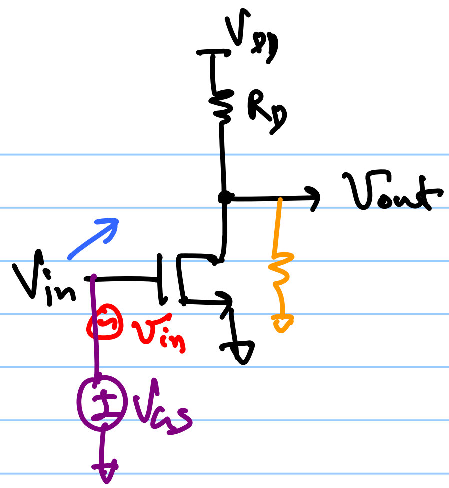
$$i_D = \frac{KP_n}{2}\frac{W}{L}(V_{GS} - V_{THN})^2 \quad , \quad \lambda = 0$$

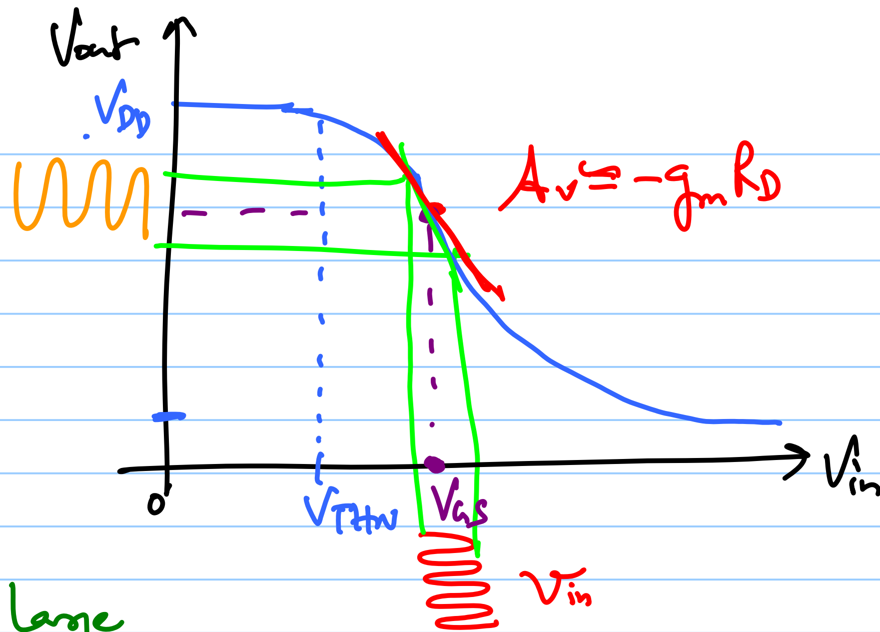
$$\frac{\partial i_D}{\partial V_{GS}} = KP_n \frac{W}{L}(v_{GS} - V_{THN})$$

$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{v_{GS}=V_{GS}} = KP_n \frac{W}{L}(V_{GS} - V_{THN})$$

$$\Rightarrow g_m = \underbrace{KP_n \frac{W}{L}}_{\beta}\underbrace{(V_{GS} - V_{THN})}_{\text{overdrive voltage, } V_{ov}} = \beta V_{ov}$$

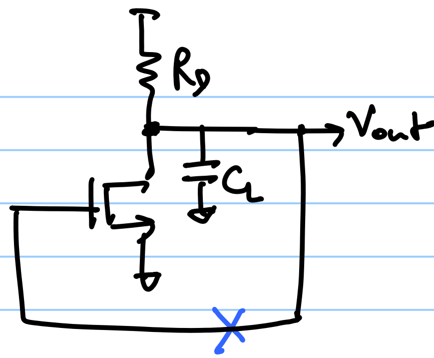
$KP_n \to \mu_n C_{ox}'$




* Looks like an inverter from large signal point of view

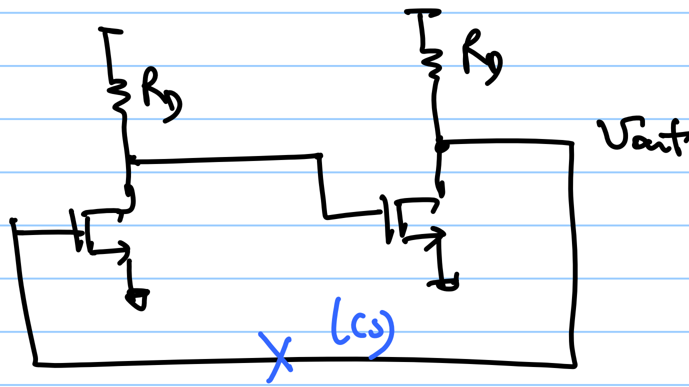
Ex. 1



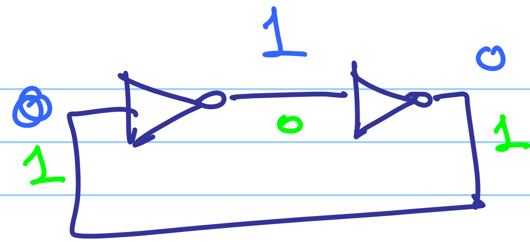

$$L(s) = \frac{-g_m R_D}{1 + s R_D C_L}$$

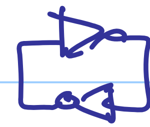
max phase shift = 90°

Ex. 2

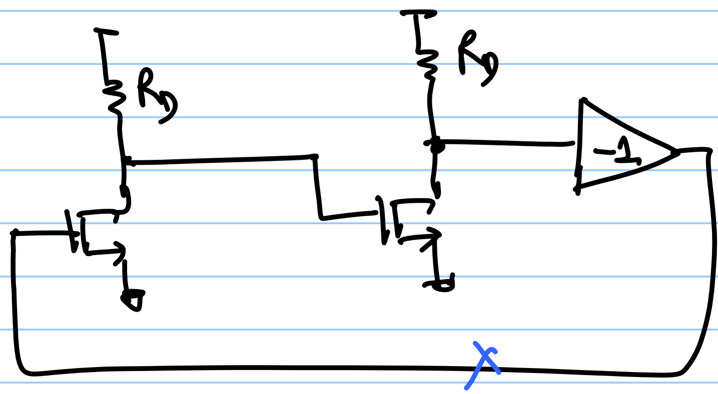



$$L(s) = \frac{(g_m R_D)^2}{(1 + s R_D C_L)^2}$$

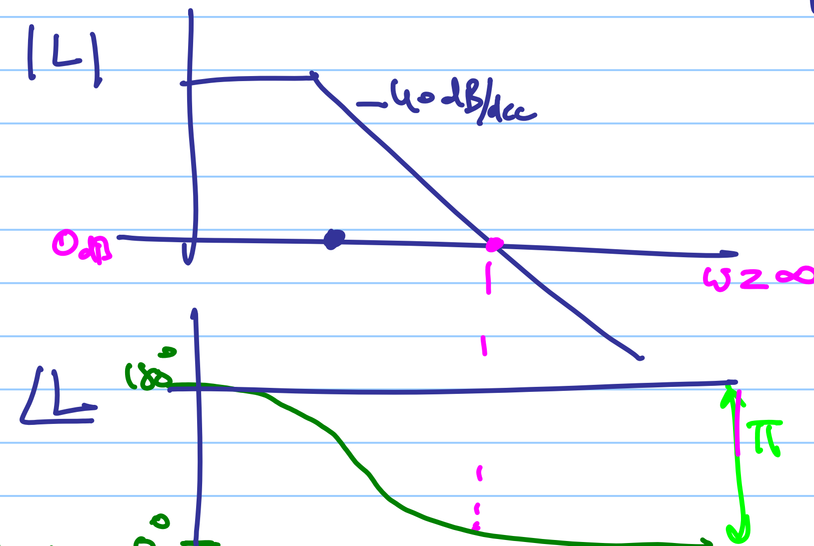


"Latch"

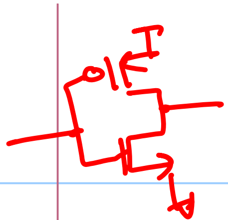


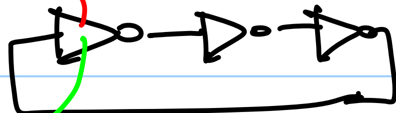

$$L(s) = \frac{-(g_m R_D)^2}{(1 + sR_DC_L)^2} \qquad \omega_p = \frac{1}{R_D C_L}$$




The excess phase shift of 180° occurs at $\omega \to \infty$

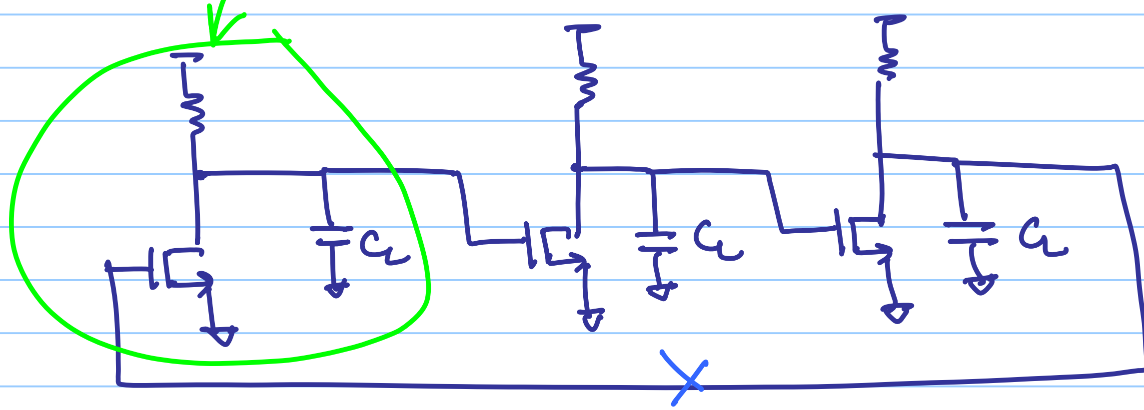
↳ doesn't satisfy the oscillation criterion





$n \geq 3$ & odd

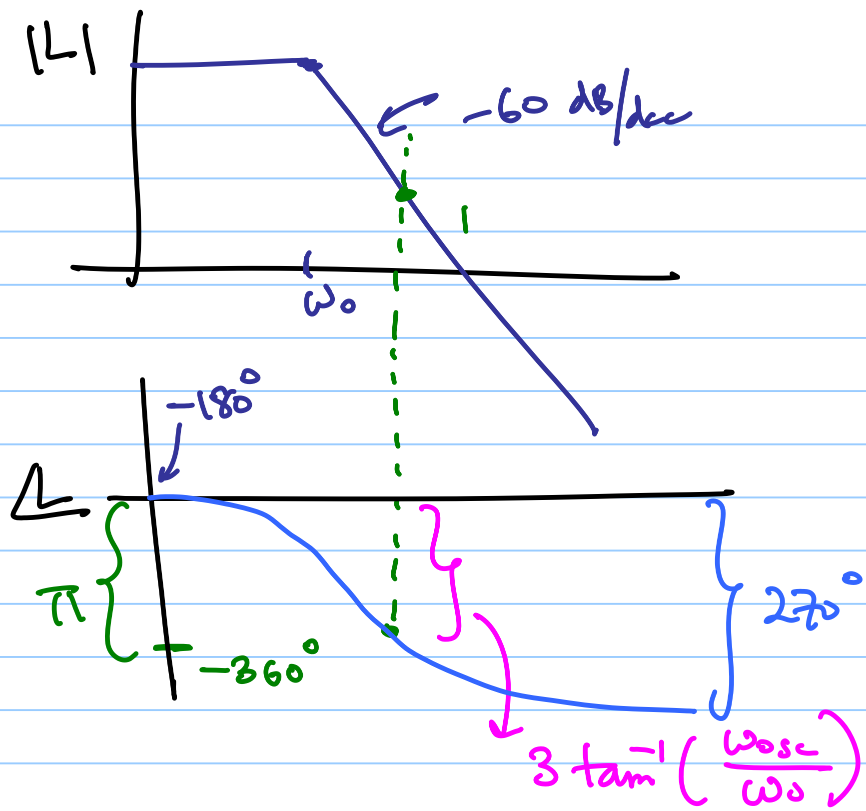
(Ring Oscillator)




$$L(s) = -\frac{A_0^3}{(1+s/\omega_0)^3}$$

where $A_0 = g_m R_D$

$\omega_0 = \frac{1}{R_D C_L}$




The circuit oscillates if excess phase

$$\angle LG(j\omega_{osc}) = 180^\circ$$

$$\cancel{3}\tan^{-1}\left(\frac{\omega_{osc}}{\omega_0}\right) = \cancel{180^\circ}\ 60^\circ$$

$$\frac{\omega_{osc}}{\omega_0} = \tan(60^\circ)$$

$$\Rightarrow \omega_{osc} = \omega_0 \tan(60^\circ)$$

$$\boxed{\omega_{osc} = \omega_0\sqrt{3}}$$

Also, the minimum gain is estimated as:

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

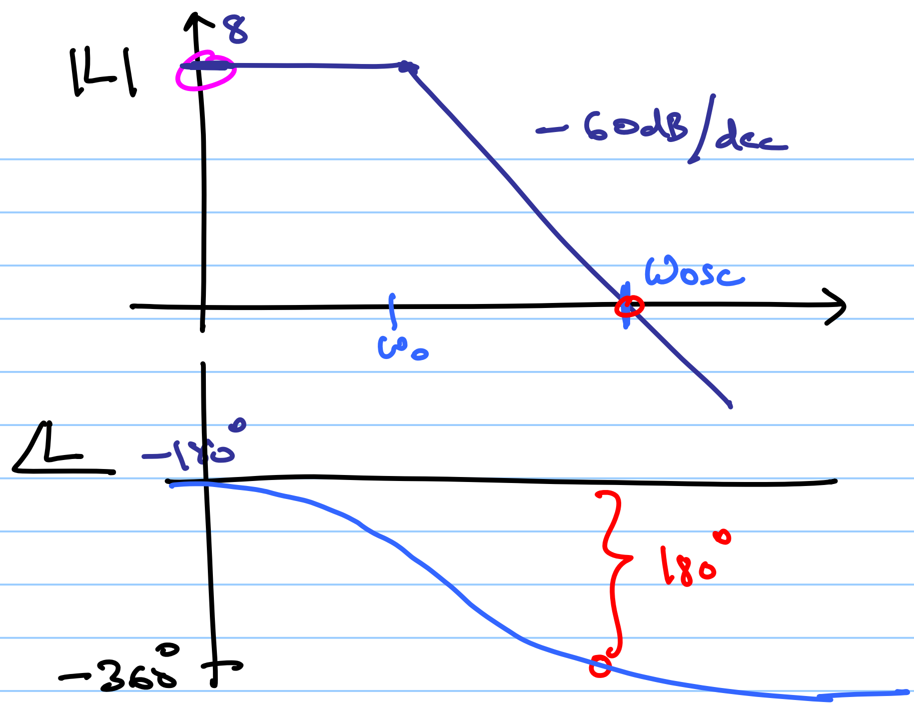
$$\Rightarrow \left(\frac{A_o}{\sqrt{1+\left(\frac{\omega_{osc}}{\omega_o}\right)^2}}\right)^3 = 1$$

$$\Rightarrow \frac{A_o}{\sqrt{1+\left(\frac{\cancel{\omega_o}\sqrt{3}}{\cancel{\omega_o}}\right)^2}} = 1$$

$$\Rightarrow \boxed{A_o = 2}$$

per stage DC gain $= 2$

$$\Rightarrow |L(\omega_{osc})| = 2^3 = 8$$




$$\Rightarrow \boxed{g_m R_D = 2}$$