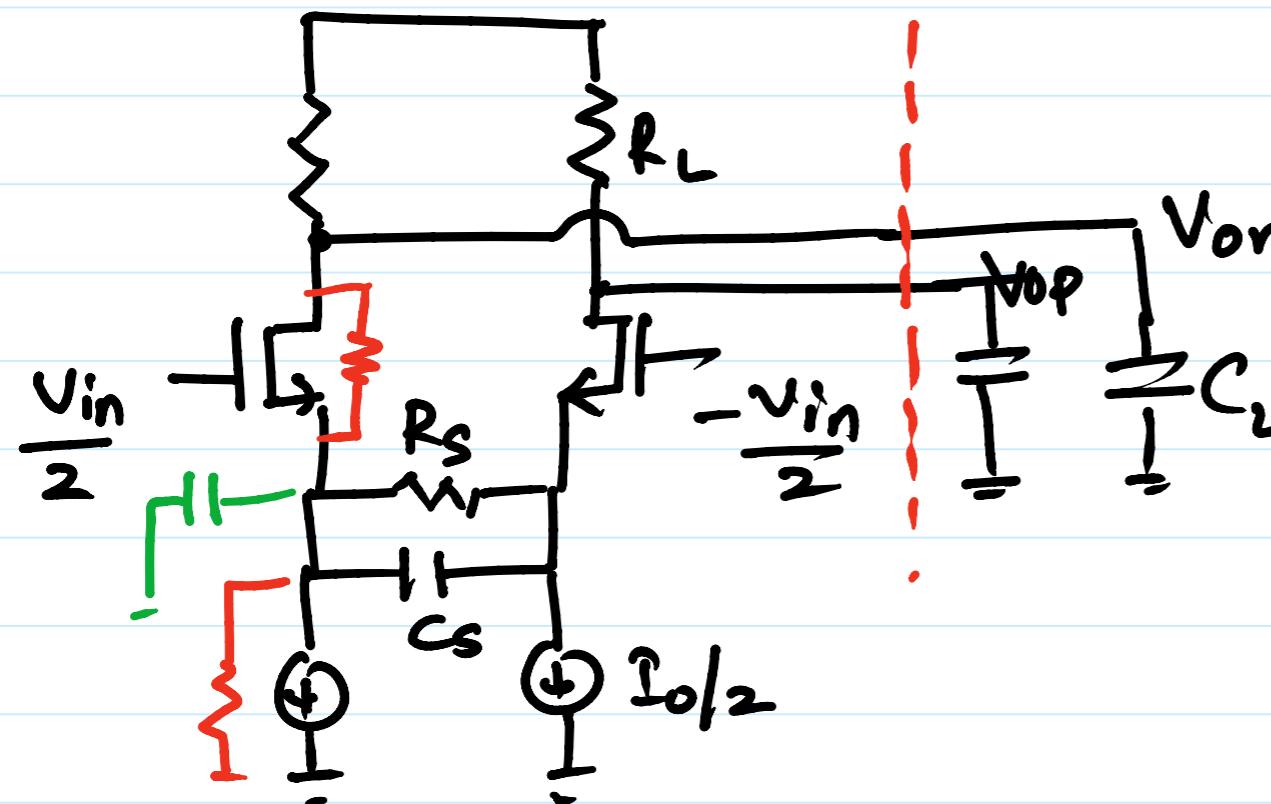


Continuous time linear Eq: (CTLE)



* C_L are fixed.

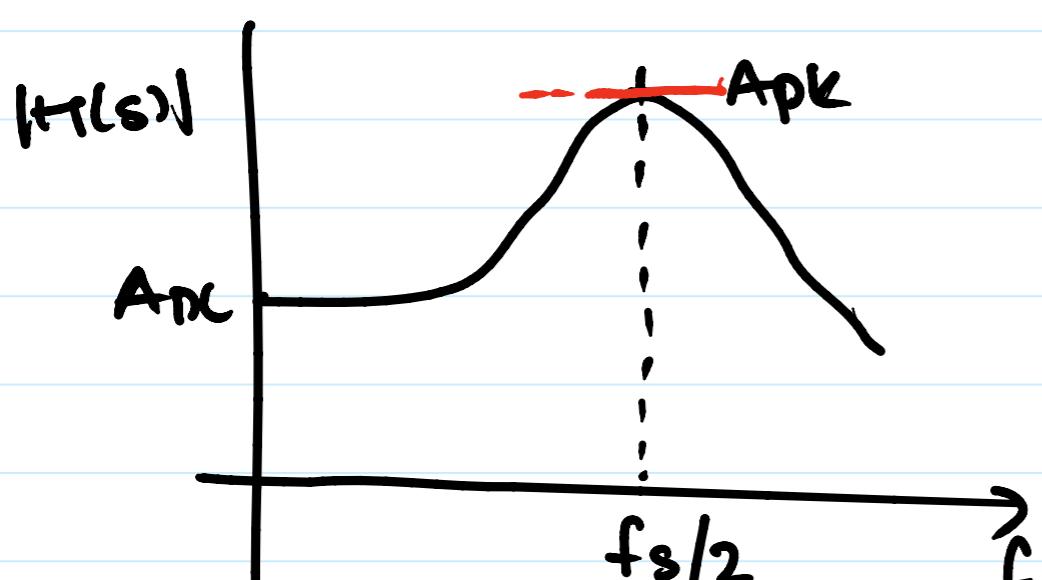
+ Channel loss $\Rightarrow \frac{A_{pk}}{A_{dc}}$

* $V_{cm,out}$ decided by the following like samplers, VCA etc.

* $\frac{g_m}{I_d}$ for input pair.

$$H(s) = A_{dc} \frac{(1 + s/\omega_z)}{(1 + s/\gamma\omega_z)(1 + s/\omega_{pk})}$$

$$A_{dc} = \frac{g_m R_L}{1 + g_m R_s}$$



$$\left| H(s) \right| \Big|_{w=w_{pk}} = \left| A_{dc} \frac{(1 + j\omega_{pk}/\omega_z)}{(1 + j\omega_{pk}/\gamma\omega_z)(1 + j\omega_{pk}/\omega_z)} \right|$$

$$\gamma = 1 + g_m R_s / 2$$

ring blocks

etc

$$\frac{1}{f_2}, \omega_2 = \frac{1}{R_s C_s}$$

$$, \omega_{p2} = \frac{1}{R_s C_s}$$

$$\frac{1}{1 + j\omega_R(\omega_{p2})} |$$

$$f_s/2 \quad f$$

f_s - data rate

$$\frac{\omega_2}{\omega_{pk}}, \frac{\omega_{p2}}{\omega_{pk}}$$

$$\left. \frac{d}{dw} |H(s)| \right|_{w=\omega_{pk}} = 0 \quad (2)$$

$$1) \quad g_m \rightarrow I_d \xrightarrow{V_{cm,out}} R_L \rightarrow \omega_{p2}$$

$C_L - C_{L0} + C_L$ (ip pair
from following load

$$A_{DC} = \frac{g_m f_L}{1 + g_m f_s/2}$$

$$2) \quad \omega_2/\omega_{pk} \text{ Common solution of eq(1) & eq(2)} \rightarrow C$$

Find minimum g_m for which (1) & (2) are satisfied

$V_{cm,out}, C_L, \text{Minimum } I \longrightarrow$ limiting ω_{pk}

CTLE FOM, =

$$\frac{A_{pk}}{A_{DC}}$$

× higher pk freq × large bw



$$\text{CTRL TUNING} = \frac{\overline{A_{DC}}}{\omega_2} \times \min(\omega_{p1}, \omega_{p2}) \times \text{far pole}$$

$$\times \frac{\omega_{p1}}{\omega_2} \times \dots \times \omega_{p2}$$

$$A_{DC} \times \frac{A_{PL}}{A_{DC}} \times b\omega$$

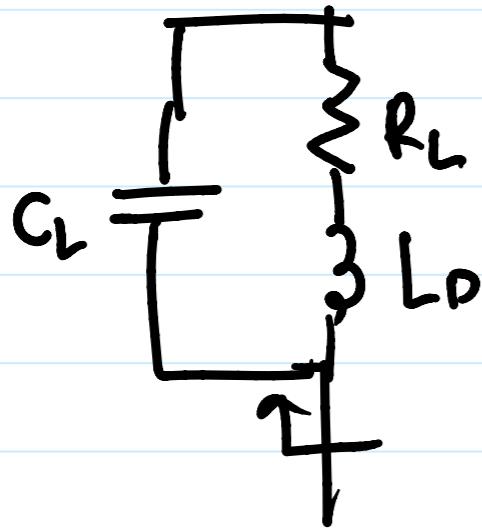
$$\frac{g_m R_L}{1 + g_m R_S / 2} \times \frac{\min(\omega_{p1}, \omega_{p2})}{\omega_2} \times \omega_{p2}$$

$$\frac{2R_L}{R_S} \times \frac{\omega_{p1}}{\omega_2} \times \omega_{p2}$$

$$\frac{2R_L}{R_S} \times \frac{\gamma \omega_2}{\omega_2} \times \frac{1}{\omega_{p2}}$$

$$\cancel{\frac{2R_L}{R_S}} \times \frac{1 + g_m R_S / 2}{g_m R_S / 2} \times \frac{1}{R_L C_L} = \boxed{\frac{g_m}{C_L}}$$

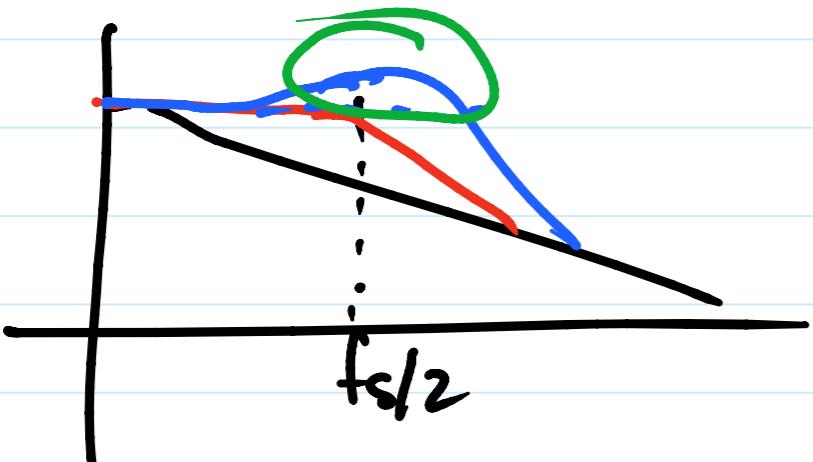
L



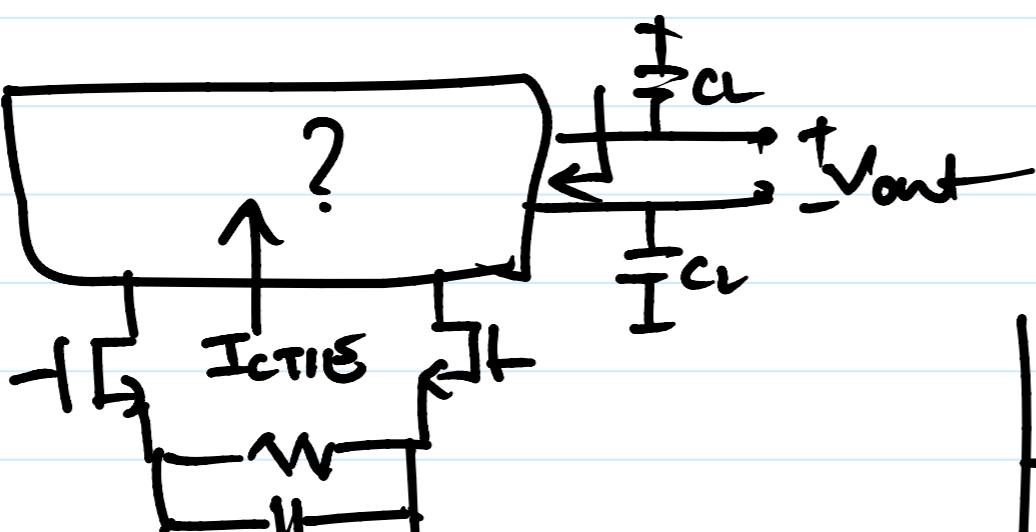
$$H(s) = A_{DC} \frac{(1 + s/\omega_2)}{(1 + s/\gamma\omega_2)} \frac{1}{(1 + s/\omega_1)}$$

$$\begin{aligned} Z_{in} &= \frac{1}{sC_L} \parallel (R_L + sL_D) \\ &= \frac{(R_L + sL_D)}{\frac{s^2 C_L L_D + sC_L R_L + 1}{sC_L}} \end{aligned}$$

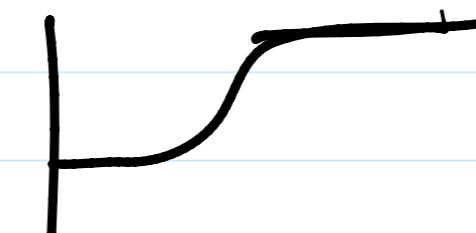
$$H(s) = A_{DC} \frac{(1 + s/\omega_2)}{(1 + s/\gamma\omega_2)}$$



over P



Ideally, $\frac{V_{out}}{I_{CTLE}}$ | low



Output pole is at high
RL vs

ω_{p2})

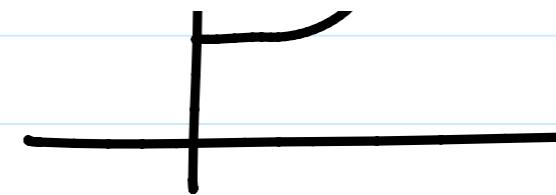
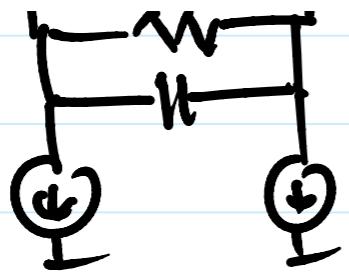
BW limitation

$$\frac{(1 + sL_o/R_L)}{1 + sC_L R_L + s^2 C_L L_D}$$

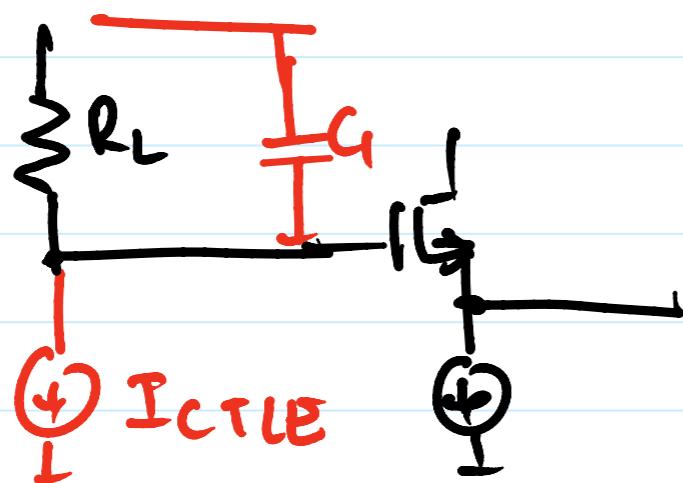
• 72x bw extension
prior dominant
ole ($Y_{R_L C_L}$)

ge dc gain

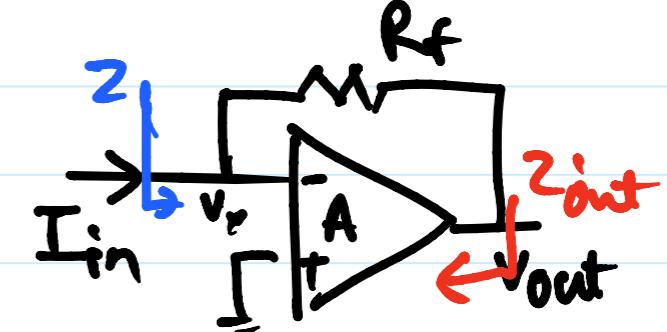
h freq.
ry low.



$\Rightarrow R_L \text{ ve}$



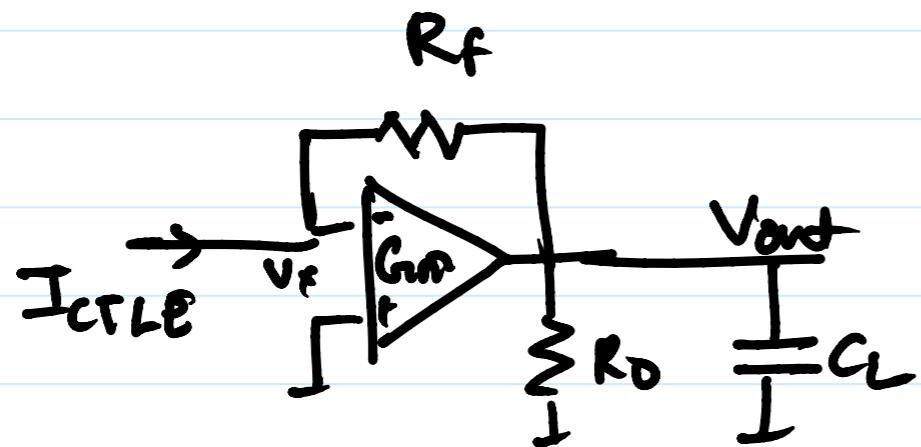
+ Large transimpedance



$$I_{in} = \frac{V_x - V_o}{R_f}$$

$$\frac{V_{out}}{I_{in}} = -\frac{R_f}{C_L}$$

$$Z_I = \frac{V_x}{I_{in}} = \frac{R_f}{C_L}$$



$Z_{out} = 0$

$$I_{CTLIE} = \frac{V_x - V_{out}}{R_f} = +G_m V_x + \frac{V_{out}}{R_D}$$

$$V_x = V_{out} + I_{rf} R_f$$

very low.

$$\frac{V_{out}}{R_f} = -\frac{V_{out}(1 + \frac{1}{A})}{R_f}$$

$$\frac{R_f}{1 + 1/A} \Big|_{A \rightarrow \infty} = -R_f$$

$$\frac{R_f}{1 + 1/A} \overline{I_{in}} \approx \frac{R_f}{1 + A}$$

$$+ V_0(sC_L)$$

t1)

$$(1 - C_{mR_f}) V_x = V_{out} \left(1 + \frac{R_f}{R_o} + s C_L R_f \right)$$

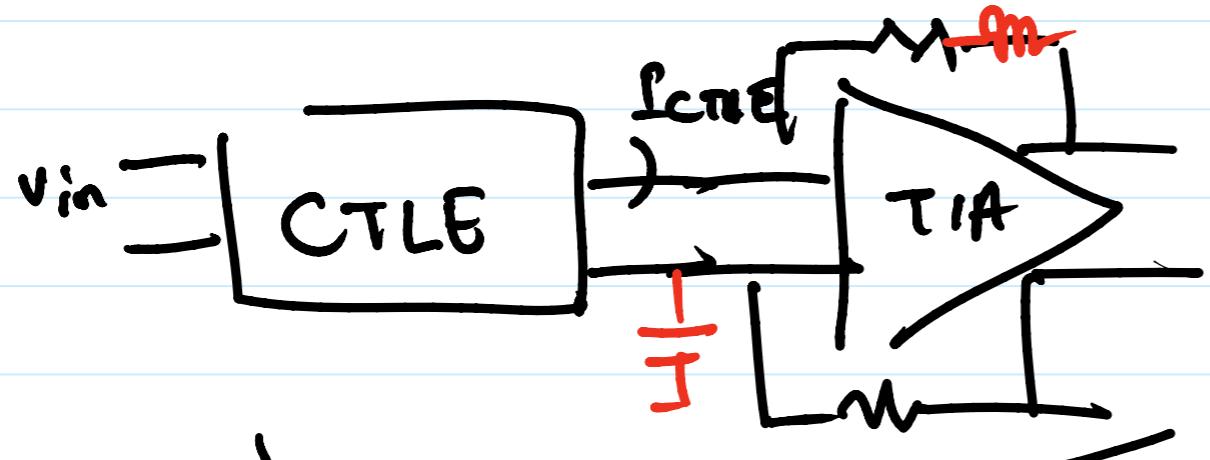
$$V_{out} + I R_f = \frac{V_{out} \left(1 + \frac{R_f}{R_o} + s C_L R_f \right)}{1 + C_m R_f}$$

$$V_{out} \left(1 + \frac{R_f}{R_o} + s C_L R_f - 1 - C_m R_f \right) = I R_f (1 + C_m R_f)$$

$$V_{out} \left(s C_L R_f + R_f \frac{(1 - C_m R_f)}{R_o} \right) = I R_f (1 + C_m R_f)$$

$$\frac{V_{out}}{I_{in}} \approx \frac{R_f}{(1 + s C_L (R_o \parallel \frac{1}{C_m}))} = \frac{R_f}{(1 + s C_L / \omega_m)}$$

$$\frac{V_{out}}{V_{in}} = \frac{g_m R_f}{1 + g_m R_f / 2} \frac{(1 + \delta / \omega_2)}{(1 + \delta / \gamma \omega_2)} \frac{1}{(1 + s C_L / \omega_m)}$$



$$FOM_1 = A_{DC} \times \frac{A_{PK}}{A_{DC}} \times \text{far} \min(\gamma \omega_2, \omega_m)$$

s_{LH}) ϵ^2)

$1 + \text{Im } R_f$)

$+ \text{Im } \delta_S$)

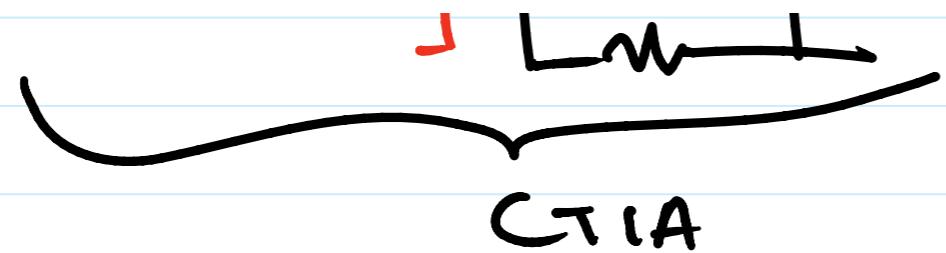
\rightarrow

Im)

Im)

ω_{p2}

' pole



$$= A_{DC} \times \frac{\min(\gamma \omega_3, \omega_{P2})}{\omega_2} \times$$

$$= \frac{2 R_f}{r_s} \times \frac{g_m R_s}{2} \times \frac{C_m}{C_L} = \frac{g_m}{C_L}$$

$$FOM_1 = \frac{A_{DC} \times \frac{A_{PC}}{A_{DC}} \times b\omega}{Power} = \frac{g_m / C_L}{V_{DD} \cdot I} = \frac{2}{V_{DD} C_L \cdot \Delta}$$

$$g_m = \frac{2I}{\Delta}$$

$$FOM_2 = \frac{\frac{g_m}{C_L} (G_m R_f)}{Power} = \frac{g_m C_m R_f}{C_L V_{DD} I} = \frac{4 R_f C}{C_L V_D}$$

$g_m \rightarrow I_1$, $C_m \rightarrow I_2$, I

$$I_1 = I_2 = \frac{I}{2}$$

$$FOM_2 = \frac{2}{C_L V_{DD} \Delta} \times \left(\frac{I R_f}{2 \Delta} \right)$$

if $\frac{I R_f}{2 \Delta} > I \Rightarrow$

ω_2

$$\underbrace{G_m R_f}_{\text{CTLE}}$$

(CTLE)

$$\frac{I_1 \times I_2}{\Delta^2} = \frac{R_f I}{C_L V_{DD} \Delta^2}$$

$$= I_1 + I_2$$

CTLE + TIA