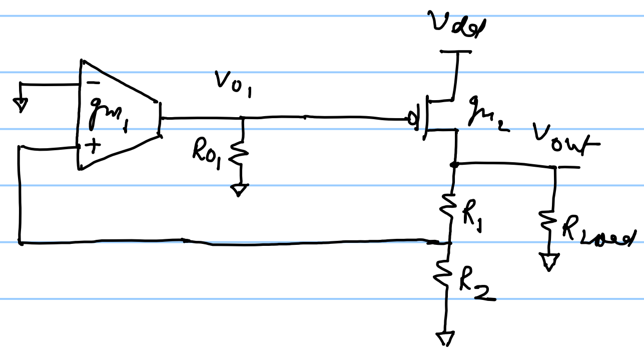
Line Regulation & Power Supply Rejection Ratio (PSRR)

Line Regulation (dc) $= \dfrac{\partial V_{out}}{\partial V_{dd}}$



$R_{out} = r_{o_2} \,||\, (R_1 + R_2) \,||\, R_{Load}$

Assume $r_{o_2} >> (R_1 + R_2) \,||\, R_{Load}$

$R_{out} = (R_1 + R_2) \,||\, R_{Load}$

$V_{o_1} = \beta \, g_{m_1} R_{o_1} V_{out}$ — (1)

Apply KCL at V_{out}

$$\frac{V_{out}}{R_{out}} - (V_{dd} - V_{o_1}) g_{m_2} = 0$$

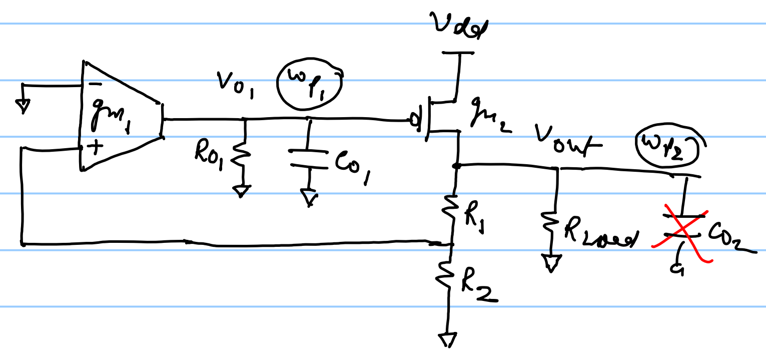
$$\frac{V_{out}}{R_{out}} + \beta g_{m_1} R_{o_1} g_{m_2} V_{out} = V_{dd} g_{m_2}$$

$$V_{out}\left[\frac{1}{R_{out}} + \beta g_{m_1} R_{o_1} g_{m_2}\right] = V_{dd} g_{m_2}$$

$$\frac{V_{out}}{V_{dd}} = \frac{g_{m_2} R_{out}}{1 + \underbrace{\beta g_{m_1} R_{o_1} g_{m_2} R_{out}}_{\gg 1}} = \frac{\cancel{g_{m_2} R_{out}}}{\beta g_{m_1} R_{o_1} \cancel{g_{m_2} R_{out}}}$$

$$\boxed{\frac{V_{out}}{V_{dd}} = \frac{1}{\beta g_{m_1} R_{o_1}}}$$

$g_{m_1} R_{o_1} \longrightarrow$ gain of error amplifier (1st stage)



for $\omega \le \omega_{ugb}$ & ω_{p_1} is dominant

we can ignore ω_2

$$V_{o_1} = \frac{\beta g_{m_1} R_{o_1}}{1 + R_{o_1} C_{o_1} s} V_{out} \quad \text{— (1)}$$

apply KCL at V_{out}

$$\frac{V_{out}}{R_{out}} - (V_{dd} - V_{o_1}) g_{m_2} = 0$$

$$\frac{V_{out}}{R_{out}} - V_{dd}\, g_{m_2} + \frac{\beta\, g_{m_1} R_{o_1} g_{m_2} V_{out}}{1 + R_{o_1} C_{o_1} s} = 0$$

$$V_{out}\left[\frac{1}{R_{out}} + \frac{\beta\, g_{m_1} R_{o_1} g_{m_2}}{(1 + R_{o_1} C_{o_1} s)}\right] = V_{dd}\, g_{m_2}$$

$$V_{out}\, \frac{1 + R_{o_1} C_{o_1} s + \overbrace{\beta\, g_{m_1} R_{o_1} R_{out} g_{m_2}}^{\gg 1}}{R_{out}(1 + R_{o_1} C_{o_1} s)} = V_{dd}\, g_{m_2}$$

$$V_{out}\, \frac{(R_{o_1} C_{o_1} s + \beta\, g_{m_1} R_{o_1} R_{out} g_{m_2})}{R_{out}(1 + R_{o_1} C_{o_1} s)} = V_{dd}\, g_{m_2}$$

$$V_{out} \approx \beta\, g_{m_1} \cancel{g_{m_2}} R_{o_1} \cancel{R_{out}} \left(1 + \frac{R_{o_1} C_{o_1} s}{\beta\, g_{m_1} R_{o_1} g_{m_2} R_{out}}\right) = V_{dd}\, \cancel{g_{m_2}} (1 + R_{o_1} C_{o_1} s) \cancel{R_{out}}$$

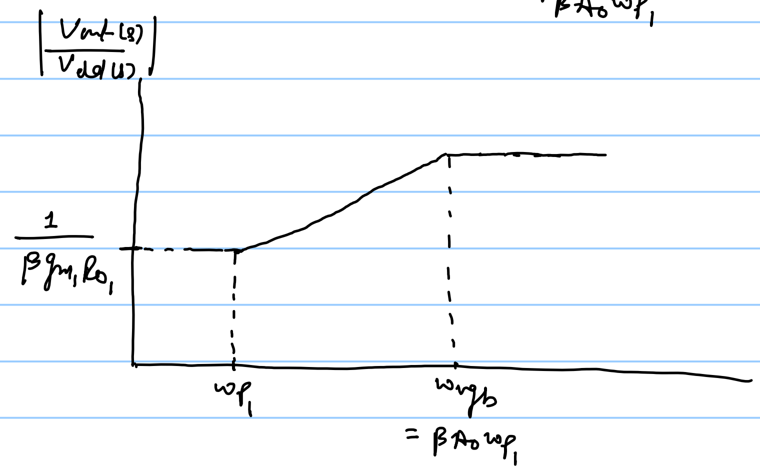
$$\frac{V_{out}}{V_{dd}} = \frac{1}{\beta\, g_{m_1} R_{o_1}} \left[\frac{1 + R_{o_1} C_{o_1} s}{1 + \frac{R_{o_1} C_{o_1} s}{\beta\, g_{m_1} R_{o_1} g_{m_2} R_{out}}}\right]$$

$$\omega_{p_1} = \frac{1}{R_{o_1} C_{o_1}}$$

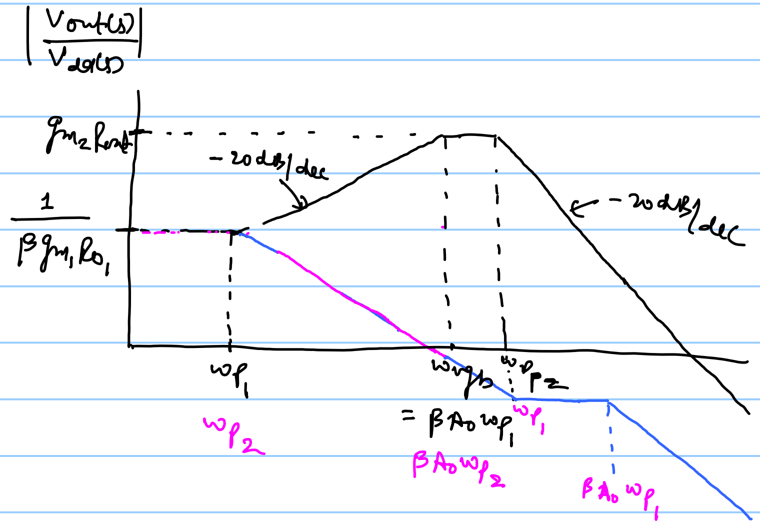
& $A_0 = g_{m_1} R_{o_1} \, g_{m_2} R_{o_2}$

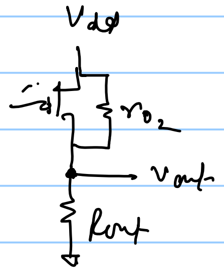
$L G(dc) = \beta A_0$

$$\frac{V_{out}(s)}{V_{dd}(s)} = \frac{1}{\beta g_{m_1} R_{o_1}} \frac{1 + s/\omega_{p_1}}{1 + s/\beta A_0 \omega_{p_1}}$$

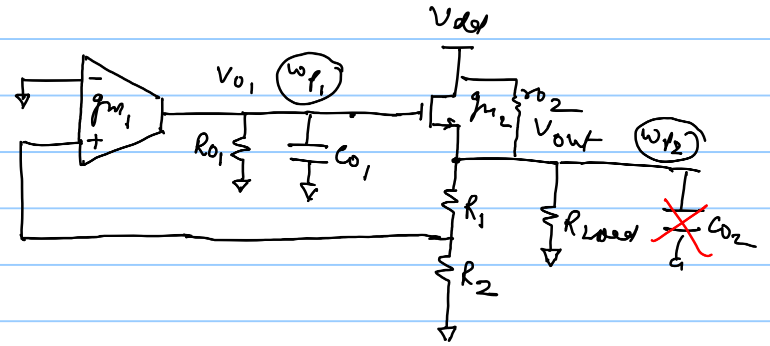


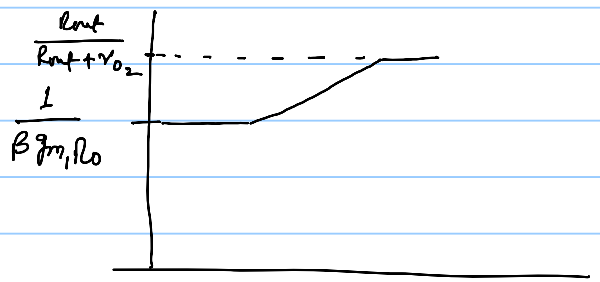
consider ω_{p_2} as well.



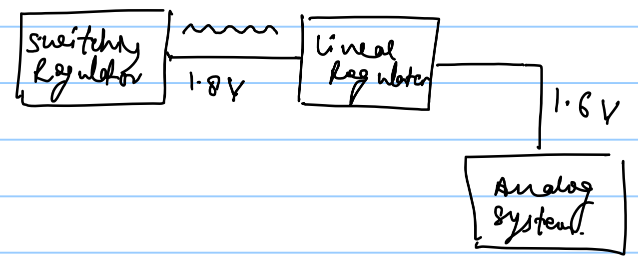


NMOS Regulator





Line Transient & PSRR in NMOS regulator is improved compared to PMOS.



switching Regulator
1.8V
Linear Regulator
1.6V
Analog system.