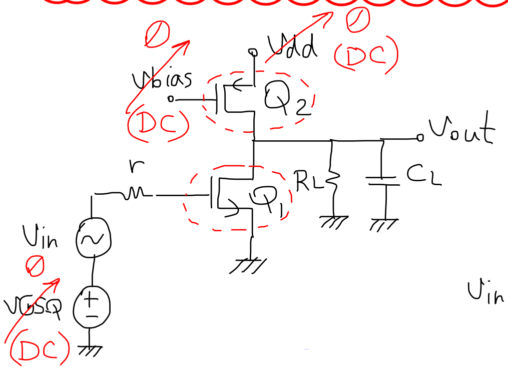
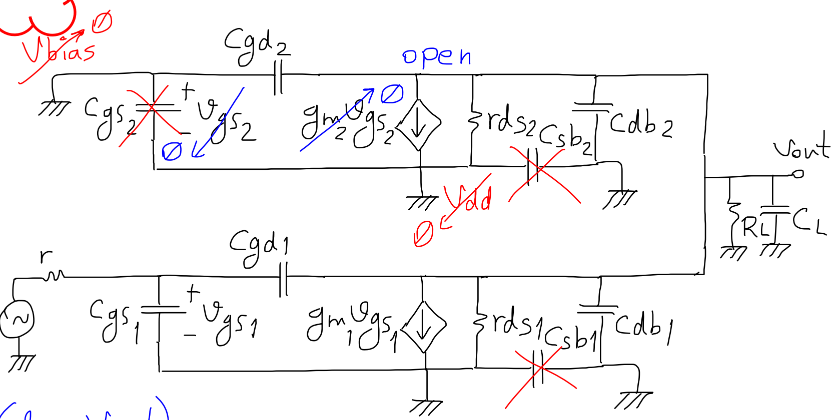
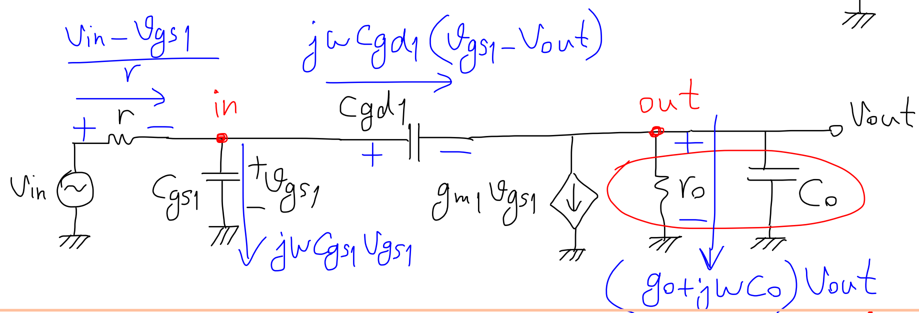
* Common Source Amplifier :







$r_o = r_{ds1} \| r_{ds2} \| R_L$

$C_o = C_{db1} + C_{db2} + C_{gd2} + C_L$

KCL (in): $g(V_{in} - v_{gs1}) = j\omega C_{gs1} v_{gs1} + j\omega C_{gd1}(v_{gs1} - V_{out})$ **(EQ.1)**

KCL (out): $j\omega C_{gd1}(v_{gs1} - V_{out}) = g_m v_{gs1} + (g_o + j\omega C_o) V_{out}$ **(EQ.2)**

$g = 1/r\,,\ g_{ds1} = \dfrac{1}{r_{ds1}}$

$a \| b = \dfrac{1}{a} + \dfrac{1}{b}$

From EQ.2 $\Longrightarrow$ $v_{gs1} = V_{out}\left[\dfrac{g_o + j\omega(C_{gd1} + C_o)}{j\omega C_{gd1} - g_{m1}}\right]$ **(EQ.3)**

From (EQs. 1 and 3) $\Longrightarrow$ $g V_{in} = V_{out}\left[-j\omega C_{gd1} + \dfrac{[g + j\omega(C_{gs1} + C_{gd1})][g_o + j\omega(C_{gd1} + C_o)]}{j\omega C_{gd1} - g_{m1}}\right]$

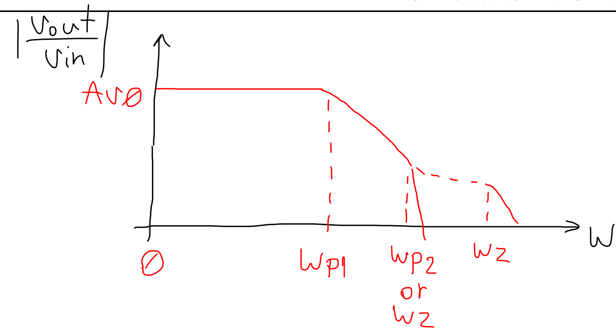
$$\Rightarrow g V_{in} = V_{out}\left[\frac{g \cdot g_o + j\omega\left(g_{m1}C_{gd1} + g(C_{gd1} + C_o) + g_o(C_{gs1} + C_{gd1})\right) + (j\omega)^2\left[C_{gs1}(C_{gd1} + C_o) + C_{gd1}C_o\right]}{j\omega C_{gd1} - g_{m1}}\right]$$

$$\Longrightarrow \boxed{\frac{V_{out}}{V_{in}} = \frac{-g \cdot g_{m1}\left(1 - j\omega\frac{C_{gd1}}{g_{m1}}\right)}{g \cdot g_o + j\omega\left[g_{m1}C_{gd1} + g(C_{gd1} + C_o) + g_o(C_{gs1} + C_{gd1})\right] + (j\omega)^2\left[C_{gs1}(C_{gd1} + C_o) + C_{gd1}C_o\right]}}$$

* All single-stage amplifiers are modelled with:

$$\frac{V_{out}}{V_{in}} = \frac{A_{vo}\left(1 \pm j\frac{\omega}{\omega_z}\right)}{\left(1 + j\frac{\omega}{\omega_{p1}}\right)\left(1 + j\frac{\omega}{\omega_{p2}}\right)} \Longrightarrow \text{Left-hand poles (inherently stable)}$$

$$\frac{V_{out}}{V_{in}} = \frac{A_{v0}\left(1 \pm j\frac{\omega}{\omega_z}\right)}{\left(1+j\frac{\omega}{\omega_{p1}}\right)\left(1+j\frac{\omega}{\omega_{p2}}\right)}$$



$$\omega_{p1} \ll \omega_{p2} \text{ or } \omega_z$$

$$\frac{V_{out}}{V_{in}} = \frac{A_{v0}\left(1 \pm j\frac{\omega}{\omega_z}\right)}{1 + j\omega\underbrace{\left[\frac{1}{\omega_{p1}} + \frac{1}{\omega_{p2}}\right]}_{\frac{1}{\omega_{p1}}} + (j\omega)^2 \frac{1}{\omega_{p1}} \cdot \frac{1}{\omega_{p2}}} = \frac{k_1\left(1 \pm j\frac{\omega}{\omega_z}\right)}{k_2 + j\omega k_3 + (j\omega)^2 k_4}$$

A_{v0} ÷ ω_{p1} ÷ ω_{p2} ÷

$$A_{v0} = \frac{k_1}{k_2}$$

$$\omega_{p1} = \frac{k_2}{k_3}$$

$$\omega_{p2} = \frac{k_3}{k_4}$$

$$\frac{1}{\omega_{p1}} \cdot \frac{1}{\omega_{p2}} = \frac{k_4}{k_2}$$

$$\frac{1}{\omega_{p2}} = \frac{k_4}{k_2} \cdot \omega_{p1} = \frac{k_4}{k_2}\,\frac{k_2}{k_3} = \frac{k_4}{k_3}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{-g \cdot g_{m1}\left(1 - j\omega\frac{C_{gd1}}{g_{m1}}\right)}{g \cdot g_o + j\omega\left[g_{m1}C_{gd1} + g(C_{gd1}+C_o) + g_o(C_{gs1}+C_{gd1})\right] + (j\omega)^2\left[C_{gs1}(C_{gd1}+C_o) + C_{gd1}C_o\right]}$$

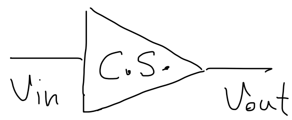
$$\Rightarrow A_{v0} = \frac{-g \cdot g_{m1}}{g \cdot g_o} = \frac{-g_{m1}}{g_o} = -g_{m1}r_o = -g_{m1}\left(r_{ds1} \| r_{ds2} \| R_L\right)$$

$$\Rightarrow \omega_z = \frac{g_{m1}}{C_{gd1}}$$ RHZ ; right hand zero

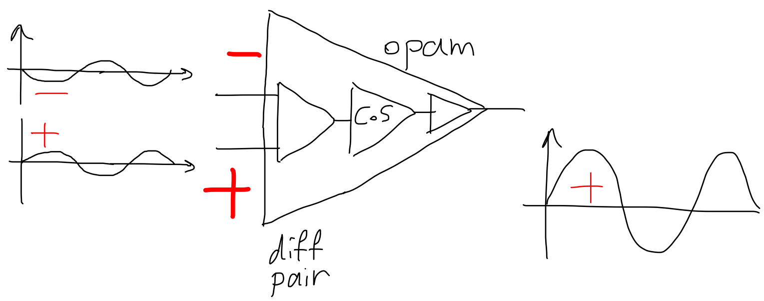
$$\Rightarrow \omega_{p1} = \frac{g \cdot g_o}{g_{m1}C_{gd1} + g(C_{gd1}+C_o) + g_o(C_{gs1}+C_{gd1})]}$$

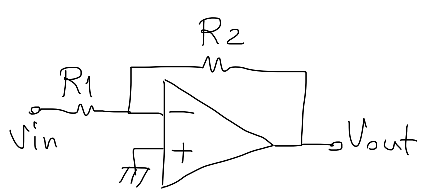
$$\Rightarrow \omega_{p2} = \frac{g_{m1}C_{gd1} + g(C_{gd1}+C_o) + g_o(C_{gs1}+C_{gd1})}{C_{gs1}(C_{gd1}+C_o) + C_{gd1}C_o}$$

*OpAmps:



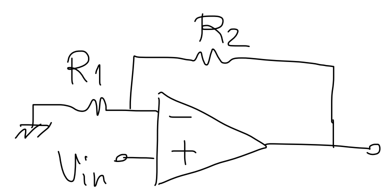
$$\frac{V_{out}}{V_{in}} \text{; open-loop gain} = \overbrace{-g_{m1}(r_{ds1} \| r_{ds2})}^{-100}$$





inverting
closed-loop

$$\frac{V_{out}}{V_{in}} = \frac{-R_2}{R_1} = \frac{100k}{1k} = -100$$



non-inverting
closed-loop

$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$$

* FOM in any Analog Design:

$P_{dc} = 1\text{mW}$ ↓

voltage swing = 800mV ↑

voltage gain = 20 ↑

bandwidth = 100 MHz ↑

$$\text{Figure of Merit (FOM)} = \frac{\text{swing} \times \text{gain} \times \text{bandwidth}}{P_{dc}}$$

Parameters needed to be increased

Parameters needed to be decreased