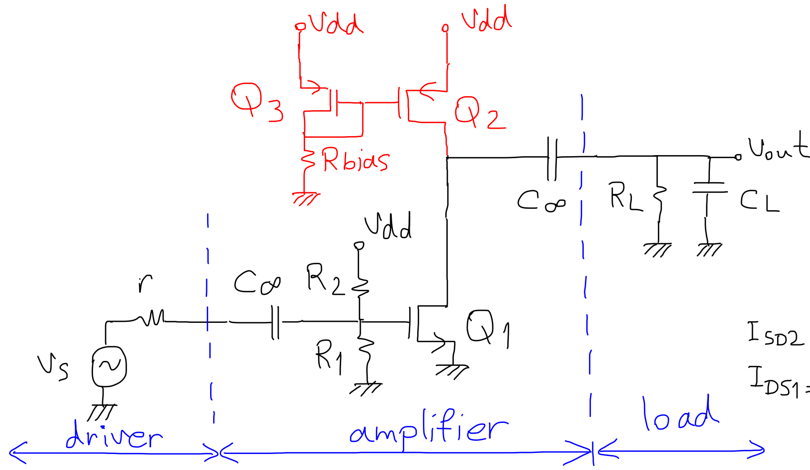
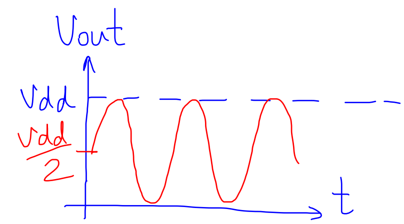
# * Common Source Amplifier parameters using indirect methods:




$$I_{SD2} = \frac{1}{2}\mu_p C_{ox}\frac{W_2}{L_2}(V_{SG2}-V_{th})^2[1+\lambda_p(V_{SD2}$$

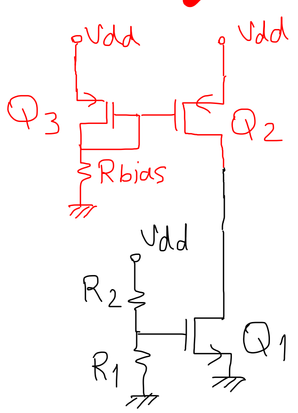
$$I_{DS1} = \frac{1}{2}\mu_n C_{ox}\frac{W_1}{L_1}(V_{GS1}-V_{th})^2[1+\lambda_n(V_{DS1}-$$

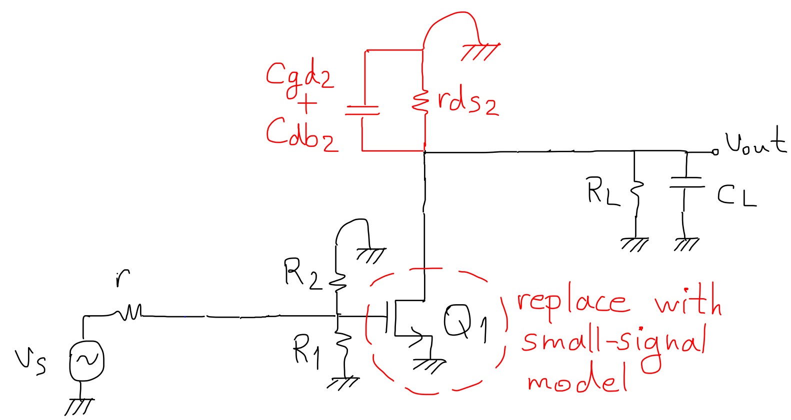
$$V_{SD2}+V_{DS1}=V_{dd}$$

$$V_{SD2}=V_{DS1}=\frac{V_{dd}}{2}$$

DC

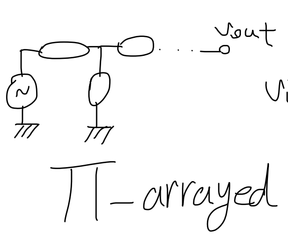
AC

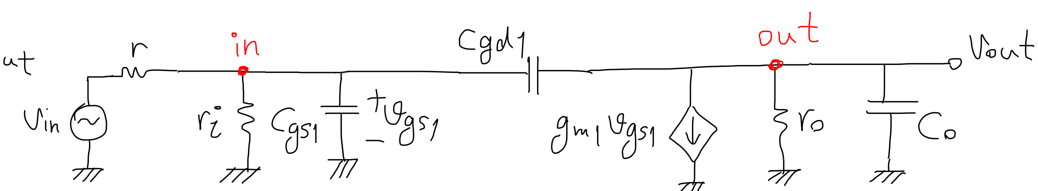



find { 1. operating points (saturation, triode)
2. small-signal parameters ($g_m$, $r_{ds}$)

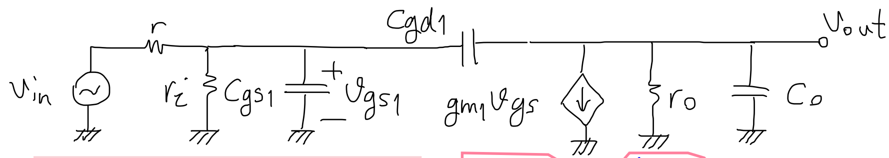
small-signal model



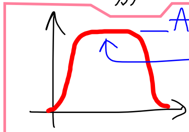

find { 1. voltage gain
2. poles, zeros
3. input/output resistors

# * Common Source Amplifier parameters using indirect methods:




$$\begin{cases} r_i = R_1 \| R_2 \\ r_o = r_{ds1} \| r_{ds2} \| R_L \\ C_o = C_{db1} + C_{gd2} + C_{db2} + C_L \end{cases}$$

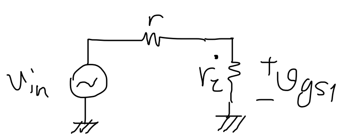
## * Find low-freq gain (mid-range)

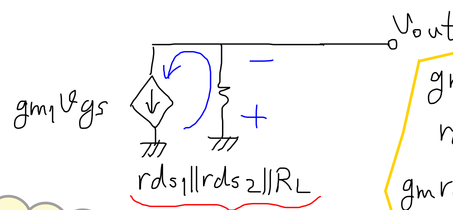



$C_\infty$: short
$C_p$: open

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

→ To find $A_{v0}$
- ↳ open all capacitors
- ↳ find $\frac{V_{out}(j0)}{V_{in}(j0)} = A_{v0}$ using KCL(in), KCL(out)



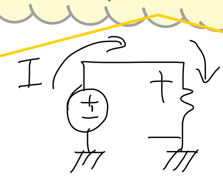

$g_m = \sqrt{2 I_{DS} \mu_n C_{ox} \frac{W}{L}}$

$r_{ds} = \frac{1}{\lambda I_{DS}}$

$g_m r_{ds} \propto \frac{1}{\sqrt{I_{DS}}}$

$$\begin{cases} V_{gs1} = V_{in} \frac{r_i}{r + r_i} \\ V_{out} = -g_{m1} V_{gs1} r_o \end{cases}$$

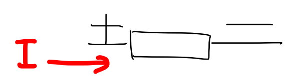
$$\Rightarrow \frac{V_{out}}{V_{in}} = A_{v0} = \frac{V_{out}(j0)}{V_{in}(j0)} = -g_{m1}\left(r_{ds1} \| r_{ds2} \| R_L\right) \frac{r_i}{r_i + r}$$



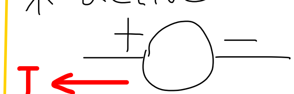

## * Find $\omega_z$

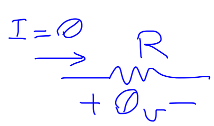
→ To find zero, use output nulling method
- ↳ find feedback component
- ↳ if it is a capacitor, write KCL(out)
- ↳ find conditions that make Vout zero

* passive R, L, C

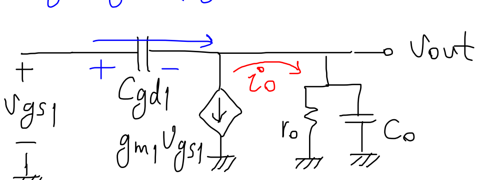



* active




$j\omega C_{gd1}(V_{gs1} - V_{out})$




$V_{out} = 0 \Longrightarrow i_o = 0$

KCL(out): $i_o = j\omega C_{gd1}(V_{gs1} - V_{out}) - g_{m1} V_{gs1}$

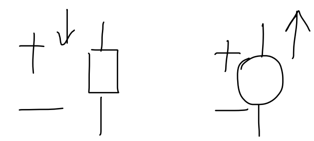
$$\Rightarrow 0 = \underbrace{(j\omega_z C_{gd1} - g_{m1})}_{0} V_{gs1} - \cancel{j\omega_z C_{gd1} V_{out}}^{\,0}$$

$$j\omega_z = \frac{g_{m1}}{C_{gd1}} \Longleftarrow$$

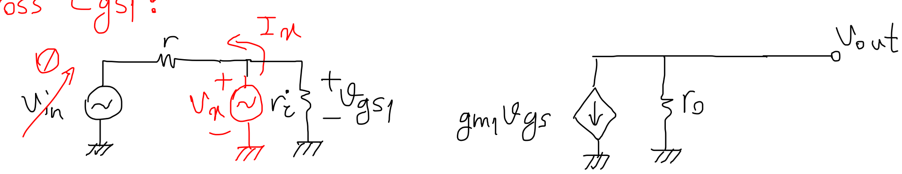
## * Find $\omega_{p1}$

→ To find $\omega_{p1}$ (first pole), use open circuit time constant method

- ↳ keep one of the capacitors $C_i$
- ↳ open all other capacitors
- ↳ find resistance $R_i$ across $C_i$
- ↳ repeat above steps for other capacitors
- ↳ $\omega_{p1} = \dfrac{1}{\sum R_i C_i}$



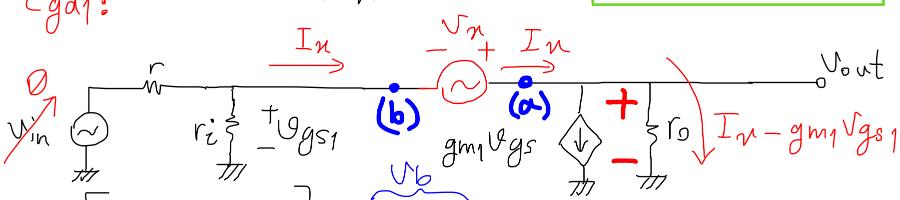
### * Across $C_{gs1}$:




$R_x$ seen across $C_{gs1}$ : $\dfrac{V_x}{I_x} = r \| r_i \Longrightarrow \boxed{\tau_1 = (r \| r_i) C_{gs1}}$

$V_x = V_a - V_b$

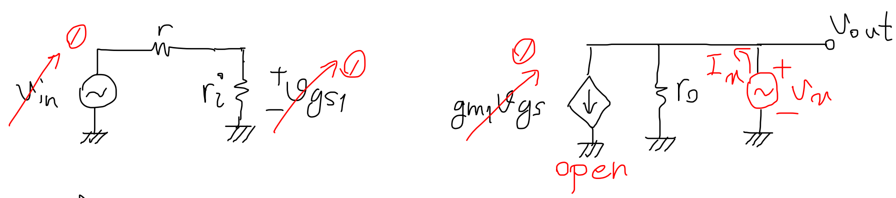
### * Across $C_{gd1}$:




$$\begin{cases} V_x = \underbrace{r_o\left[I_x - g_{m1}V_{gs1}\right]}_{V_a} - \overbrace{V_{gs1}}^{V_b} \\ V_{gs1} = -(r \| r_i) I_x \end{cases} \Longrightarrow R_x = \frac{V_x}{I_x} = r \| r_i + r_o + g_{m1} r_o (r \| r_i)$$

$$\boxed{\tau_2 = \left[r \| r_i + r_o + g_{m1} r_o (r \| r_i)\right] C_{gd1}}$$

### * Across $C_o$:



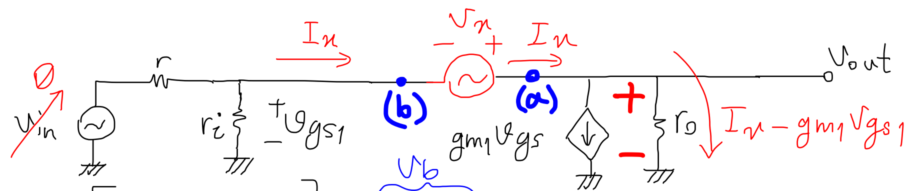

$R_x = \dfrac{V_x}{I_x} = r_o = r_{ds1} \| r_{ds2} \| R_L$

$$\boxed{\tau_3 = (r_{ds1} \| r_{ds2} \| R_L)(C_{db1} + C_L + C_{gd2} + C_{db2})}$$

$$\omega_{p1} = \frac{1}{\tau_1 + \tau_2 + \tau_3}$$

=> Finding the Resistance across Cgs1 in more details : ....

$$V_x = V_a - V_b$$

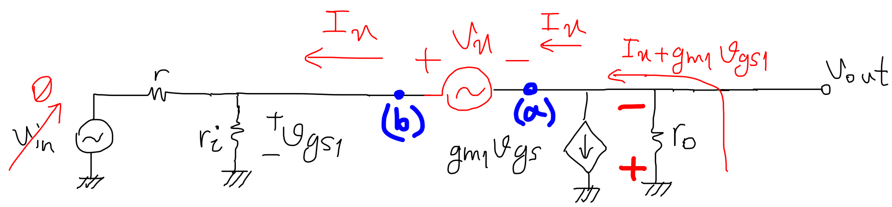



$$\begin{cases} V_x = \underbrace{r_o\left[I_x - g_{m1}V_{gs1}\right]}_{V_a} - \overbrace{V_{gs1}}^{V_b} \\ V_{gs1} = -(r\|r_i)\,I_x \end{cases}$$

$$\Longrightarrow R_x = \frac{V_x}{I_x} = r\|r_i + r_o + g_{m1}r_o(r\|r_i)$$

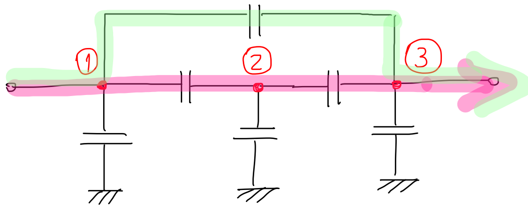
$$\tau_2 = \left[r\|r_i + r_o + g_{m1}r_o(r\|r_i)\right]C_{gd1}$$

$$V_x = V_b - V_a$$




$$\begin{cases} V_x = \overbrace{v_{gs1}}^{V_b} - \overbrace{\left(-r_o\left[I_x + g_{m1}v_{gs1}\right]\right)}^{V_a} \\ v_{gs1} = I_x(r\|r_i) \end{cases}$$

* If we have multiple poles & zeros in the circuit: ....




$$\tau_1 = C_{t_1} \cdot R_{t_1}$$

$$\tau_1 < \tau_2 < \tau_3$$

$$\omega_{p1} = \frac{1}{\tau_1 + \tau_2 + \tau_3}$$

$$\frac{V_{out}(j\omega)}{V_{in}(j\omega)} = A_{v0} \frac{\left(1 + j\frac{\omega}{\omega_{z1}}\right)\left(1 + j\frac{\omega}{\omega_{z2}}\right)}{\left(1 + j\frac{\omega}{\omega_{p1}}\right)\left(1 + j\frac{\omega}{\omega_{p2}}\right)\left(1 + j\frac{\omega}{\omega_{p3}}\right)}$$

because there are two capacitive paths from input to output

becaus circuit has three nodes

$$\omega_{p1} < \omega_{p2} < \omega_{p3}$$