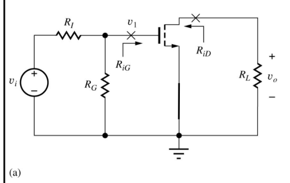
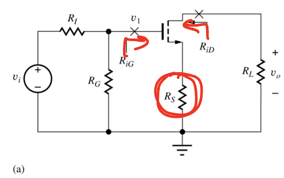
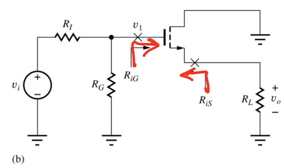
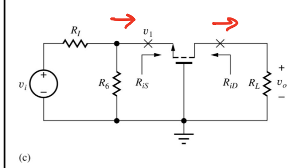
Common Source (CS)	CS with Degeneration	Common Drain (CD)	Common Gate (CG)
			
$A_{V,t} = -g_m R_L$ $R_i = \infty$ $R_o = r_o$ $A_{I,t} = \infty$	$A_{V,t} = -\frac{g_m R_L}{1+g_m R_S}$ $R_i = \infty$ $R_o = \left[r_o\left(1+g_m R_E\right)\right]$ $A_{I,t} = \infty$ Without degeneration: Simply set $R_S = 0$	$A_{V,t} = \frac{R_L}{\frac{1}{g_m} + R_L}$ $R_i = \infty$ $R_o = \frac{1}{g_m}$ $A_{I,t} = \infty$	$A_{V,t} = g_m R_L$ $R_i = \frac{1}{g_m}$ R_S $R_o = \left[r_o\left(1+g_m R_E\right)\right]$ $A_{I,t} \approx 1$

MOS	Common Source (CS)	Common Source with Deg.	Common Drain (CD)	Common Gate (CG)
R_i	∞	∞	∞	Small $\frac{1}{g_m}$
R_o	Large	Very Large	Small $\frac{1}{g_m}$	Large very Large
A_V	Moderate	Small	~ 1	Moderate
f_H	Small	< Moderate	< Large ✓	Large ✓

2-Port Model

	Ideal R_{in}	Ideal R_{out}
Voltage Amplifier	∞	0
Current Amplifier	0	∞
Transconductance Amplifier	∞	∞
Transresistance Amplifier	0	0

V_{in} I_{out}
I_{in} V_{out}

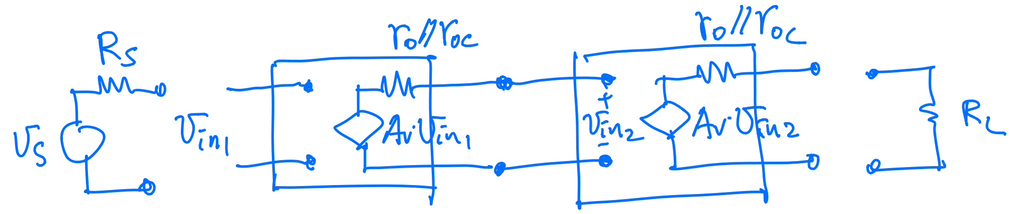
Multi-Stage Amplifiers

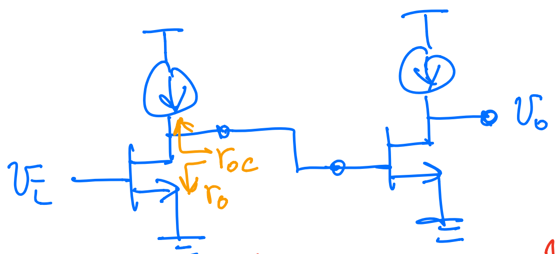
* 3 stages: input stage = match R_{in}
  middle " = provide gain
  output " = match R_{out}

* Higher gain
* Improve bandwidth

* DC coupled amplifier → level shift

Example : 2 stage Amp : CS + CS





$$A_V = \left(\frac{R_{in}'}{R_S + \underset{\infty}{R_{in}'}}\right)^{\nearrow 1} \cdot A_{V_1} \cdot \left(\frac{R_{in2}}{R_{out1} + \underset{\infty}{R_{in2}}}\right)^{\nearrow 1} \cdot A_{V_2} \cdot \left(\frac{R_L}{R_{out2} + R_L}\right)$$

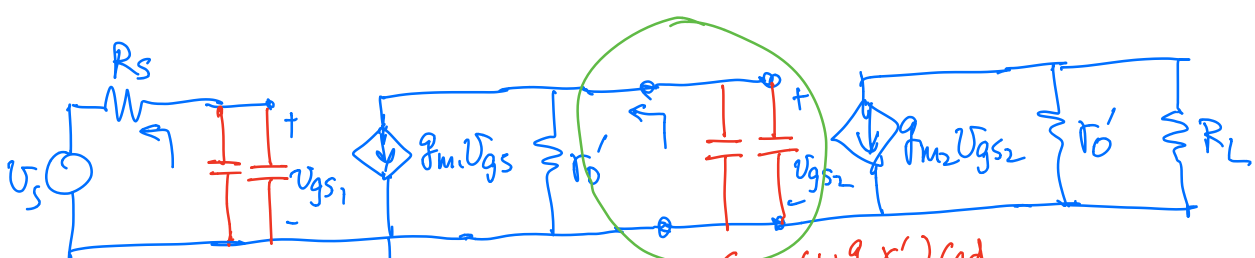
$$A_{V_1} = -g_{m_1} \cdot (r_o // r_{oc} // \underset{\infty}{R_{in2}}) = -g_{m_1}(r_o // r_{oc})$$

$$A_{V_2} = -g_{m_2}(r_o // r_{oc})$$

small

$$A_V = [g_{m_1}(r_o // r_{oc})][g_{m_2}(r_o // r_{oc})] \frac{R_L}{r_o // r_{oc} + R_L}$$

Bandwidth : Hybrid-π



$C_{gs} + (1 + g_m r_o') C_{gd}$ $\quad$ $r_o' = r_o // r_{oc}$ $\quad$ $C_{gs} + (1 + g_m r_o') C_{gd}$

$$\tau_1 = [C_{gs} + (1 + g_{m_1} r_o') C_{gd}] \cdot R_S \leftarrow$$

$$\tau_2 = [C_{gs} + (1 + g_{m_2} r_o') C_{gd}]\, r_o' \rightarrow \text{super long}$$

large cap

$r_o \parallel r_{oc}$ = large resistance

$$\omega_H = \frac{1}{\tau_1 + \tau_2} = \text{super small}$$

2 disadvantages for CS+CS

① Large output resistance R_{out}, → lower gain

② Very Low Bandwidth

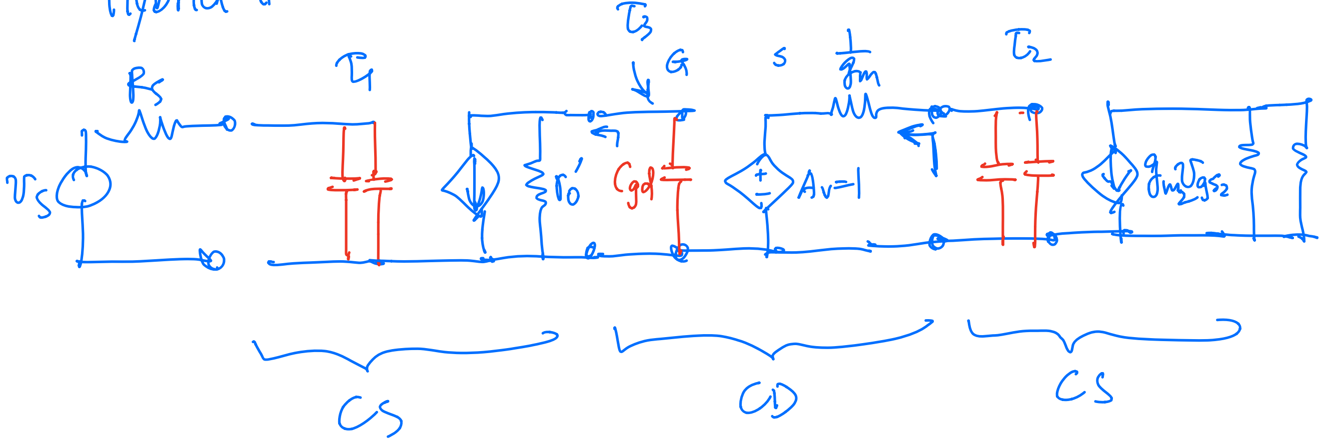
Solution: CS + CD + CS

unity gain

$R_{in} = \infty$

$R_{out} = \frac{1}{g_m}$

Hybrid-π



$$A_V = A_{V1} A_{V2} \cdot A_{V3} \frac{R_L}{R_{out} + R_L}$$ same

$A_{V2} = 1$

$\tau_1 = R_S (C_{gs} + (1 + g_m r_o') C_{gd})$ same

$\tau_2 = \frac{1}{g_m} (C_{gs} + (1 + g_m r_o') C_{gd})$ substantially reduce

$\tau_3 = r_o' \cdot C_{gd}$ small ,

$\uparrow$ $\uparrow$ small

$\omega_H = \dfrac{1}{\tau_1 + \tau_2 + \tau_3} > \omega_H$ of CS + CS