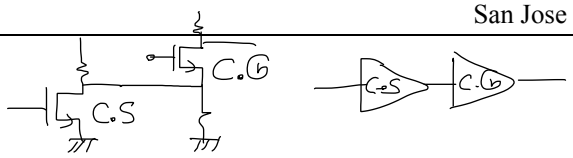
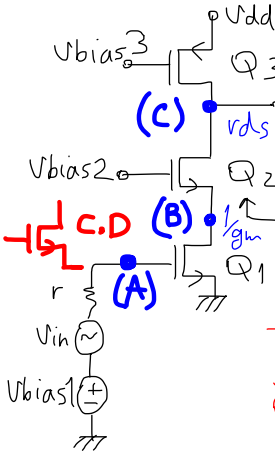
* Cascode Amplifier:



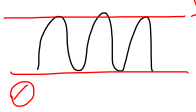


$$A_{v0_2} = g_{m_2}(r_{ds_2} \| r_{ds_3})$$

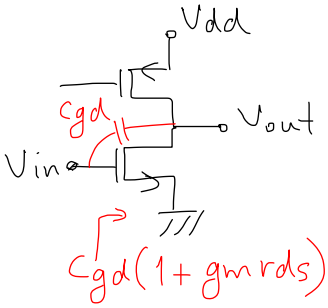
$$r_{out} = r_{ds_3} \| (g_{m_2} r_{ds_2} r_{ds_1}) = r_{ds_3}$$

$$R_{D1} = \frac{r_{ds_2} + r_{ds_3}}{1 + g_{m_2} r_{ds_2}}$$

$$A_{v0_1} = -g_{m_1}(r_{ds_1} \| R_{D1})$$



$$r_{ds_2} = \frac{1}{\lambda_n I_{DS2}}, \quad r_{ds_3} = \frac{1}{\lambda_P I_{SD3}}, \quad I_{DS2} = I_{SD3}$$



$$A_{v0} = A_{v0_1} \cdot A_{v0_2} = -g_{m_1}\left(r_{ds_1} \| \frac{r_{ds_2}+r_{ds_3}}{1+g_{m_2}r_{ds_2}}\right) g_{m_2}(r_{ds_2} \| r_{ds_3})$$

ignore

$$= -2 g_{m_1}(r_{ds_2} \| r_{ds_3})$$

$$g_m r_{ds} \gg 1 \Rightarrow r_{ds} \gg \frac{1}{g_m}$$

small

$$\Rightarrow A_{v0} = -g_{m_1} g_{m_2}(r_{ds_2} \| r_{ds_3})\left(r_{ds_1} \| \frac{\frac{1}{\lambda_n}+\frac{1}{\lambda_P}}{\frac{1}{\lambda_n}} \times \frac{1}{g_{m_2}}\right)$$

$$\Rightarrow A_{v0} = -g_{m_1}(r_{ds_2} \| r_{ds_3})\left[1 + \frac{\lambda_n}{\lambda_P}\right] \equiv \text{comparable to the gain of the common source amplifier}$$

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

$$\tau_1 = r \cdot \left[C_{gs_1} + \left(1 + \frac{g_{m_1}}{g_{m_2}}\left(1+\frac{\lambda_n}{\lambda_P}\right)\right) C_{gd_1}\right]$$

$C_{gs}, C_{gd}, C_{db}, C_{sb}$

$$\tau_2 = \left[r_{ds_1} \| \frac{r_{ds_2}+r_{ds_3}}{1+g_{m_2}r_{ds_2}}\right]\left[C_{gd_1} + C_{db_1} + C_{sb_2} + C_{gs_2}\right]$$

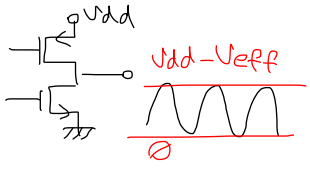
$$\tau_3 = \left[\left(r_{ds_1} + r_{ds_2} + g_{m_2} r_{ds_2} r_{ds_1}\right) \| r_{ds_3}\right]\left(C_{gd_2} + C_{db_2} + C_{gd_3} + C_{db_3}\right)$$

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

; bandwidth of the cascode amplifier is larger than the bandwidth of the common source amplifier

* For Common Source Amplifier:

$$\tau = r\underbrace{\left[C_{gs_1} + \left(1 + g_{m_1}(r_{ds_1} \| r_{ds_2})\right) C_{gd_1}\right]}_{C_{in}} + \underbrace{(r_{ds_1} \| r_{ds_2})\left[C_{gd_1} + C_{db_1} + C_{gd_2} + C_{db_2} + C_L\right]}_{C_{out}}$$



* Comparison of cascode and C.S. amplifiers:

cascode

same gain

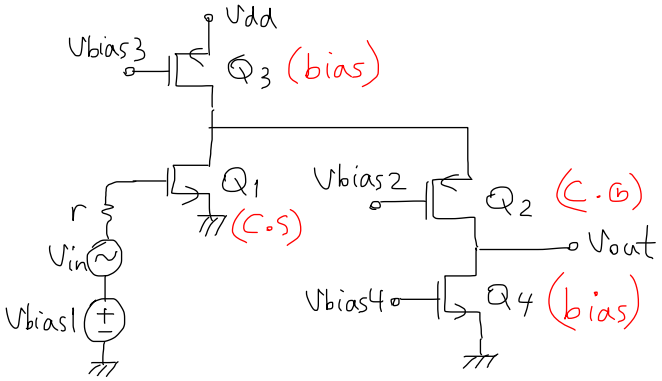
slightly higher bandwidth

better isolation

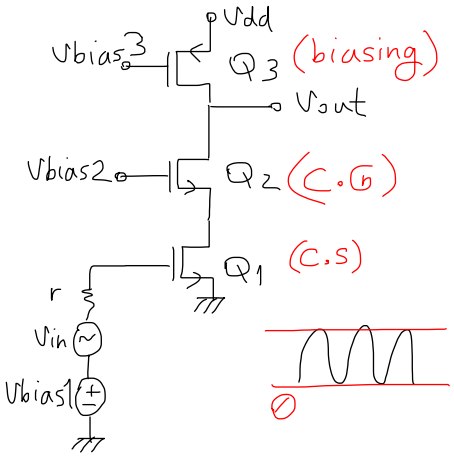
C.S.

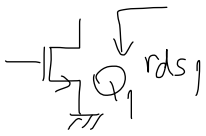
higher swing

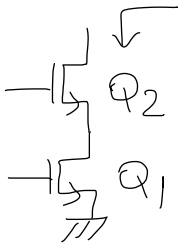
* Folded cascode amplifiers:



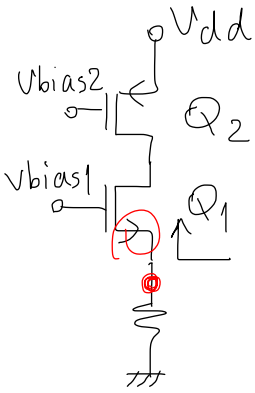
* cascode





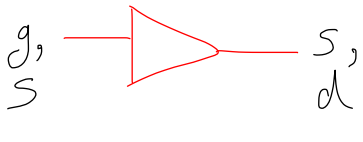


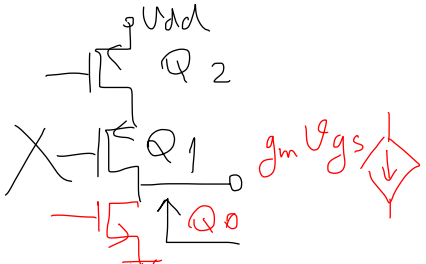
$g_{m2} r_{ds2} r_{ds1} + r_{ds2} + r_{ds1}$



$\times \quad g_{m1} r_{ds1} r_{ds2}$

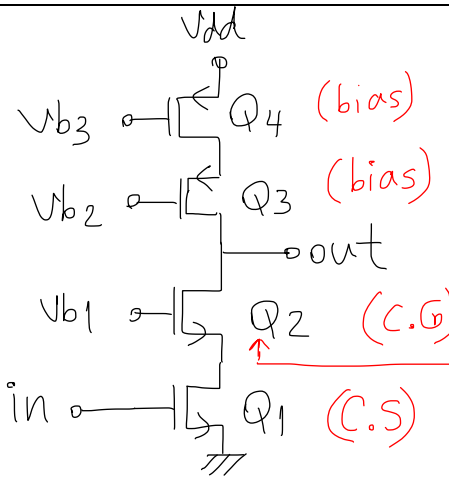
$\frac{r_{ds1} + r_{ds2}}{1 + g_{m1} r_{ds1}}$





$g_{m1} r_{ds1} r_{ds2} + r_{ds1} + r_{ds2}$

$-g_{m0}(r_{ds0} \| [\quad])$

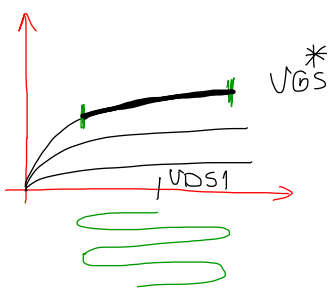


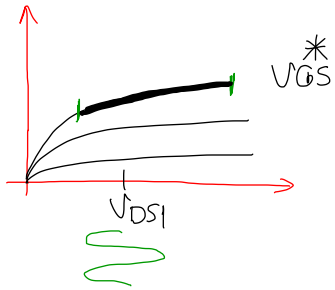
$$R_{x1} = \frac{r_{ds2} + [r_{ds3} + r_{ds4} + g_{m3} r_{ds3} r_{ds4}]}{1 + g_{m2} r_{ds2}} \approx r_{ds}$$

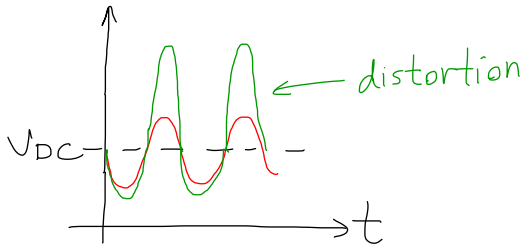
(dominant)

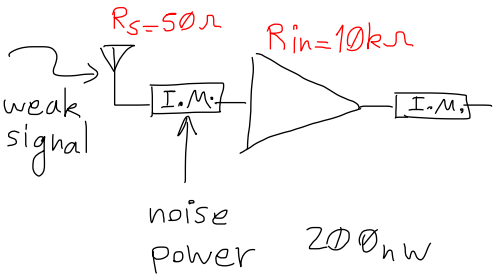
$$A_{v01} = -g_{m1}(r_{ds1} \| R_{x1}) \approx -g_m \frac{r_{ds}}{2}$$

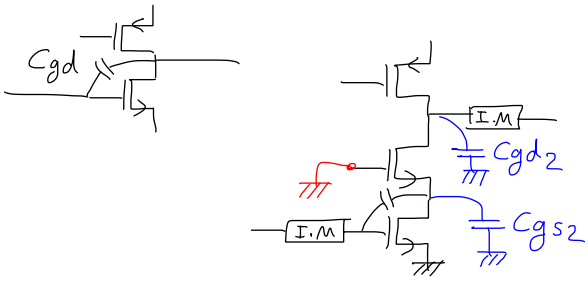
$$A_{v02} = g_{m2}\left(r_{ds2} \| \left[g_{m3} r_{ds3} r_{ds2} + r_{ds2} + r_{ds3}\right]\right) = g_{m2} r_{ds2}$$



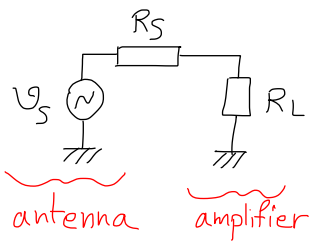


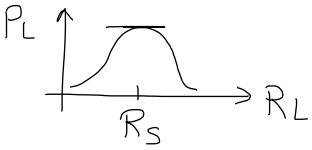


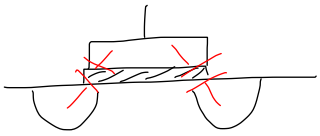


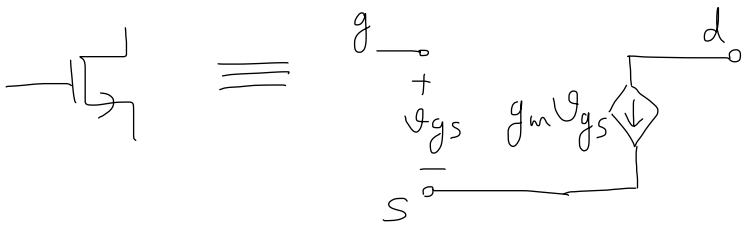


signal power > noise power

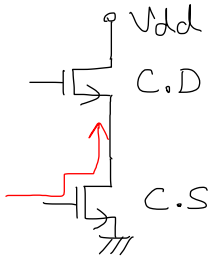








input	output
✓ g	d → C.S
✓ s	d → C.G
✓ g	s → C.D
X d	g, s
X s	g
✓ C.S + C.G	
X C.S + C.D	



C.S C.D C.G	S.D.	Cascode C.S (n-type), C.G (n-type) folded-cascode C.S (n-type), C.G (p-type) diff-pair (n-type)