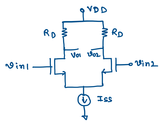
* Gain limitation of MOS- Differential pair



→ The typical gain of MOS- Differential Amplifier is very low. (less than 10).

→ The Differential gain

$|A_d| = g_m R_D$

→ To increase the gain either R_D or g_m needs to be increased.

→ If R_D is increased, then voltage drop across the resistor R_D increases.

→ Therefore, to keep the MOSFETS into saturation, more supply voltage V_{DD} is required.

*

Transconductance

$g_m = \sqrt{2 I_D \mu_n C_{ox} \left(\frac{W}{L}\right)}$

→ As per the above eqn, g_m can be increased either by increasing the bias currents (I_D) or by increasing ($\frac{W}{L}$) ratio.

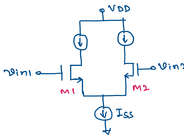
→ If bias current is increased, then power consumption increases.

→ If W/L ratio is increased then overall area required by the amplifier increases.

→ In modern day IC's, to keep the size and power consumption within limit, both parameters (I_D and W/L) can't be increased beyond certain limit.

→ Therefore, the gain of typical MOS- Differential amplifier is limited.

* MOS- Differential Amp^r with current source load:



→ With ideal current source, the differential gain

$|A_d| = g_m r_o$ r_o → output resistance of MOSFETS

→ The actual current source has finite output resistance.

∴ Differential gain $|A_d| = g_m [r_o \| R_o]$

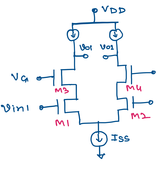
Where, R_o → output resistance of current source

r_o → output resistance of MOSFETs

* Using current source as a load, there is a marginal improvement in the gain.

→ Using cascode configuration the gain can be increased further.

* Cascode Differential Amplifier:



* For ideal current sources,

Differential gain $|A_d| \approx g_{m1}(g_{m3} r_{o3} r_{o1})$

where, $g_{m3} r_{o3} r_{o1}$ ~ output impedance of cascode stage

* With actual current source (with finite output impedance of current source)

$|A_d| \approx g_{m1} [g_{m3} r_{o3} r_{o1} \| R_o]$

where, R_o → output resistance of current source.

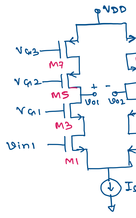
If $R_o \ll g_{m3} r_{o3} r_{o1}$, then

Differential gain $|A_d| \approx g_{m1} R_o$

→ If R_o is small, then overall gain is comparable to typical MOS- Differential pair.

→ Therefore, to take the advantage of cascode stage, the output resistance of current source should be high enough.

* Using cascode current source along with the cascode differential Amplifier, the gain can be increased.



The differential gain

$|A_d| \approx g_{m1} [R_{on} \| R_{op}]$

$R_{on} \approx g_{m3} r_{o3} r_{o1}$

$R_{op} \approx g_{m5} r_{o5} r_{o7}$

→ Using this cascode configuration along with cascode current source, the differential gain of the amplifier can be improved significantly.