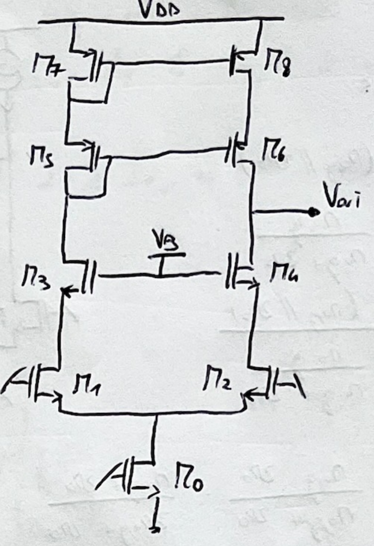
Single - Stage OTA

• **Telescopic Cascode**

This structure has a cascode both on the upper and lower side with respect to V_{OUT}, so $g_m R_{OUT} \simeq \frac{\mu^2}{2}$

[DRAWBACK: reduced voltage swing]



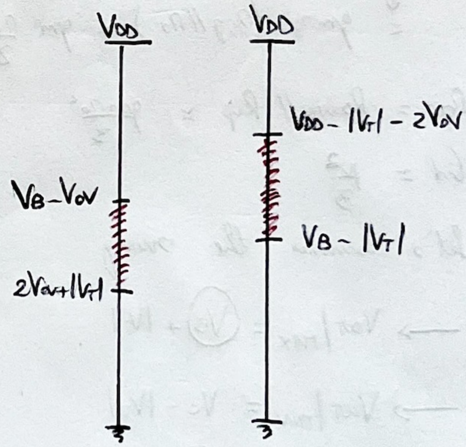
→ $V_{OUT}|_{MAX} = V_{DD} - V_{SG,8} - V_{OV,6}$

note that we may improve it by using an ENHANCED MIRROR

→ $V_{OUT}|_{MIN} = V_B - |V_T|$

→ $V_{CM}|_{MAX} = V_B - V_{GS,4} + |V_T| = V_B - V_{OV}$

→ $V_{CM}|_{MIN} = V_{OV,0} + V_{GS,1} = 2V_{OV} + |V_T|$



Now, if we increase V_B we

INCREASE the common mode swing

DECREASE the output swing

and viceversa if we decrease V_B.

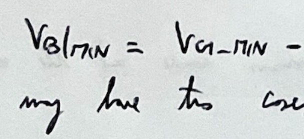
We have that

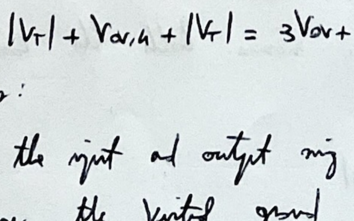
$$V_B|_{MAX} = V_{DD} - V_{SG,8} - V_{OV,6} = V_{DD} - 2V_{OV} - |V_T|$$

$$V_B|_{MIN} = V_{CM\_MIN} - |V_T| + V_{OV,4} + |V_T| = 3V_{OV} + |V_T|$$

We may have two cases:

- BUFFERS, we need the input and output swing to overlap as much as possible
- INVERTING CONFIGURATION, the virtual ground doesn't pose requirements on the common mode range





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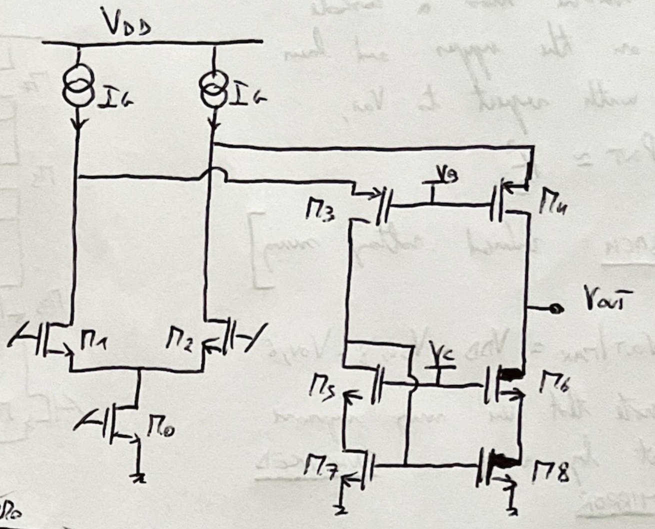
- <u>FOLDED CASCODE</u>

We avoid the series of many transistors in order to recover voltage swing

Let's compute the output resistance:



$R_{DOWN} = g_m r_o^2$

$R_{UP}^{(0)} \simeq g_m r_o (r_{o,g} \,//\, 2r_o)$

$G_{LOOP}(0) = -\dfrac{r_{o,g}}{r_{o,g} + 2r_o}$

$\Downarrow$

$$R_{UP} = \frac{g_m r_o (r_{o,g} \,//\, 2r_o)}{1 + \dfrac{r_{o,g}}{r_{o,g} + 2r_o}}$$

$$= g_m r_o \frac{r_{o,g} \cdot 2r_o}{\cancel{r_{o,g} + 2r_o}} \cdot \frac{\cancel{r_{o,g} + 2r_o}}{2r_{o,g} + 2r_o} =$$

$$= g_m r_o (r_{o,g} \,//\, r_o) \simeq g_m \frac{r_o^2}{2}$$

$R_{OUT} = R_{DOWN} \,//\, R_{UP} \simeq \dfrac{g_m r_o^2}{3}$

$G_d \simeq \dfrac{\mu^2}{3}$

Let's consider the swing

$\begin{cases} \longrightarrow V_{OUT}|_{MAX} = V_B + |V_T| \\ \longrightarrow V_{OUT}|_{MIN} = V_C - |V_T| \end{cases}$

BIG DEAL!

$\begin{cases} \longrightarrow V_{OI}|_{MAX} = V_B + |V_{SG,3}| + |V_T| \\ \longrightarrow V_{OI}|_{MIN} = V_{OV,0} + V_{GS,1} = |V_T| + 2V_{OV} \end{cases}$

Note that by unbiasing V_B we worsen both the common mode and the output swing.

$V_B|_{MAX} = V_{DD} - V_{OV,G} - |V_{GS,4}|$

$V_B|_{MIN} = V_{OUT,MIN} - |V_T|$

- <u>SLEW RATE PERFORMANCE</u>

Let's consider I_0 current of M_0. The bias current of the two branches $M_3 - M_4$ will be $I_G - \frac{I_0}{2}$. To set I_G we need to consider that when the stage is fully unbalanced (for example M_2 off) then we have that the current through M_3 will be $I_G - I_0$ and at the output we have I_0

If $I_G < I_0$, then M_3 and all his branch turns off, the potential of node (A) drops until when M_1 and M_0 go ohmic, thus matching $I_G = I_0'$. On the M_4 branch instead, I_G increases the potential of the output node, thus switching off M_4, or driving it into ohmic in order to match the needed output current, thus driving also I_G ohmic.
In this way nodes (A) and (B) reach voltages close to supply or ground, thus charging the stray capacitors and slowing down the circuit.
Therefore, not to degrade the performances, we need $I_G \geq I_0$, so more power dissipation.