Tail Current Source Resistance in Common-Mode Gain of Diff. Amplifier

Dr. Anil Kumar Gundu

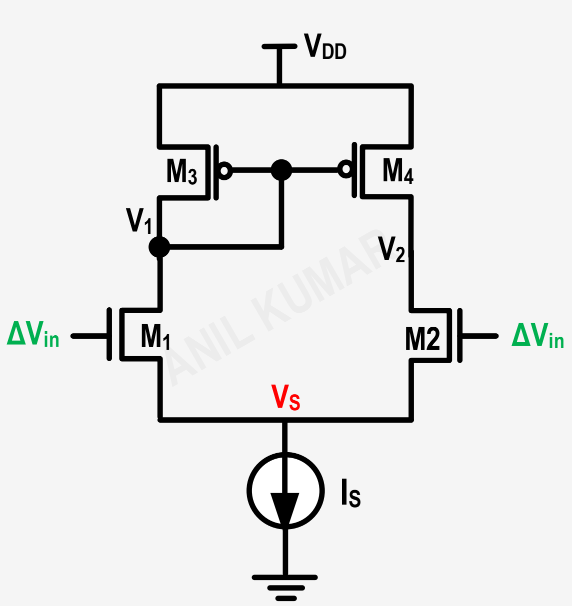
Role of Tail Current Source Resistance in Common-Mode Gain (I)

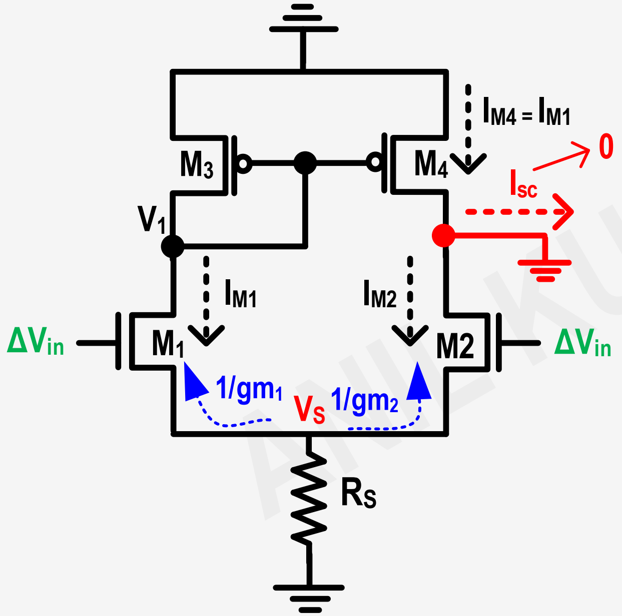
What is the impact of the tail current source's finite output resistance on the common-mode gain of a differential amplifier employing an active and perfectly matched current mirror if :

(i) the channel length modulation (CLM) of $M_1 – M_4$ are zero

(ii) The channel length modulation of M_1, M_2 is zero but the channel length modulation of transistors M_3 and M_4 is non-zero

Case (i) : The common-mode gain remains zero when the channel length modulation (CLM) of M_1, M_2, M_3, and M_4 is zero, even with a finite output resistance in the tail current source. This is because identical currents through M_1 and M_2 result in a zero short-circuit current, as the current mirror (M_3–M_4) replicates this current. Thus, zero transconductance (G_m) leads to a zero common-mode gain.





$$I_{M1} = I_{M2} = \frac{g_m}{1+2g_mR_s}\Delta V_{in}$$

$$I_{M3} = \frac{g_m}{1+2g_mR_s}\Delta V_{in}$$

If M3 and M4 matched perfectly

$$I_{M4} = \frac{g_m}{1+2g_mR_s}\Delta V_{in}$$

$$I_{sc} = 0$$

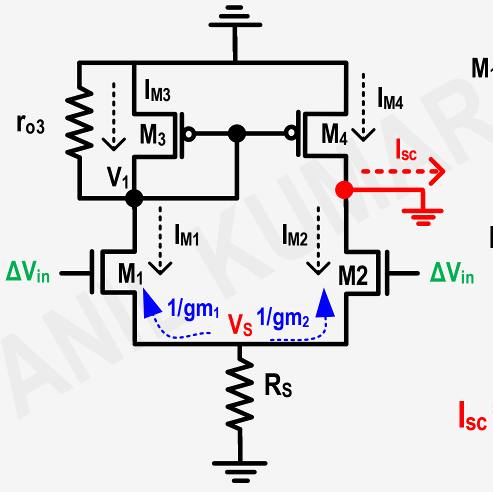
Role of Tail Current Source Resistance in Common-Mode Gain (II)

What is the impact of the tail current source's finite output resistance on the common-mode gain of a differential amplifier employing an active and perfectly matched current mirror if :

(i) the channel length modulation (CLM) of M_1 , M_2, M_3, and M_4 are zero

(ii) The channel length modulation of M_1, M_2 is zero but the channel length modulation of transistors M_3 and M_4 is non-zero

Case (ii) : I_{M1} spilts between r_{o3} and $1/g_{m3}$. A fraction of current mirrored to M_4 and hence the structure exhibits transconductance. The output impedance looking into the output is r_{o4} (as CLM = o for M_1 and M_2) which eventually lead to a negative common-mode gain. To mitigate this, the transconductance multiplied by a source resistance ($2g_mR_S$) should be significantly larger than 1, implying that the sizing of input devices like M_1 and M_2 needs to be larger than that of the tail current source.



M_1 and M_2 are matched ($gm_1 = gm_2$)

M_3 and M_4 are matched (but $\lambda \neq 0$)

$$I_{M1} = I_{M2} = \frac{g_m}{1+2g_mR_s}\Delta V_{in}$$

$$I_{M4} = \frac{g_{m3}r_{o3}}{1+g_{m3}r_{o3}} I_{M1}$$

$$I_{sc} = \frac{-1}{1+g_{m3}r_{o3}} \frac{g_m}{1+2g_mR_s}\Delta V_{in}$$

$$A_{CM} = \frac{-1}{1+g_{m3}r_{o3}} \frac{g_m r_{o4}}{1+2g_mR_s}$$

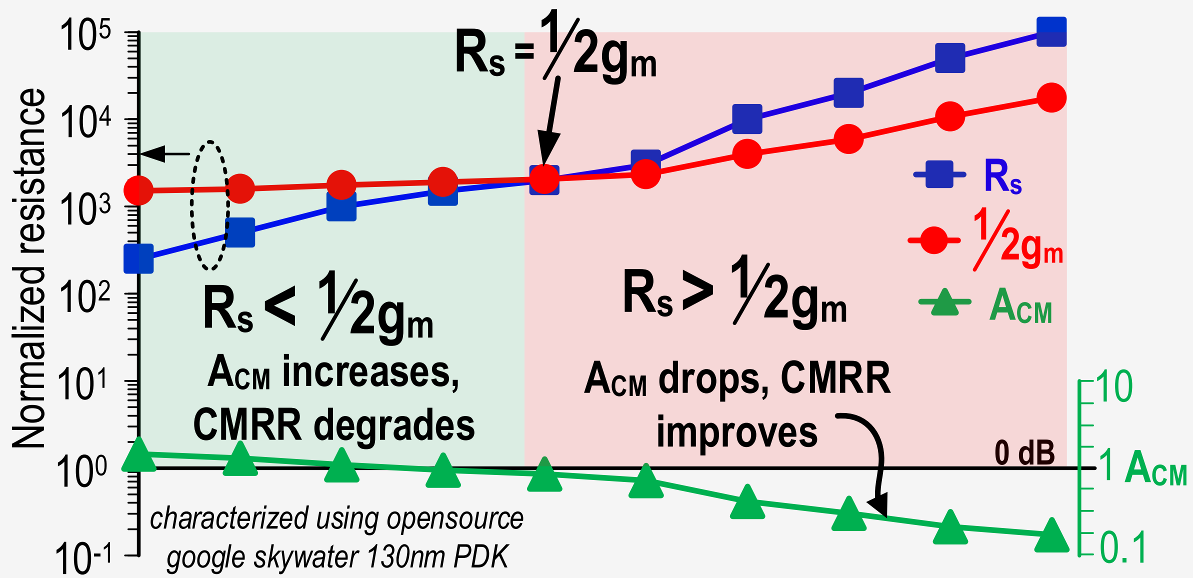
For lower common-mode gain,

$2g_mR_s >> 1$

$R_s >> 1/2g_m$

$I_{M1}R_s >> V_{od,M1}/4$

$$V_S >> \frac{V_{od,M1}}{2}$$



ANIL KUMAR