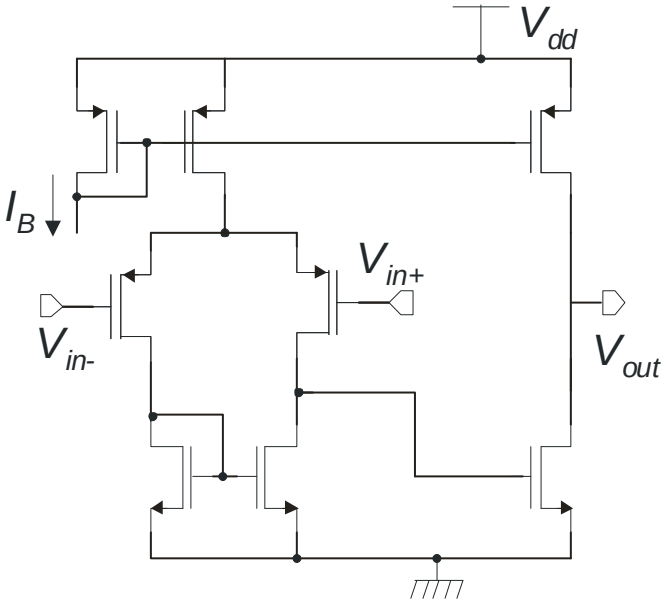
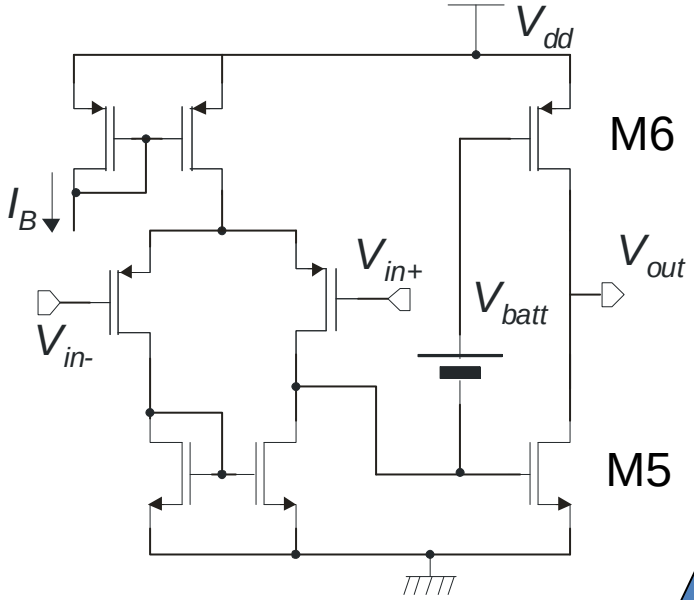
Two stage – Class AB Op-Amp: principle



Class - A



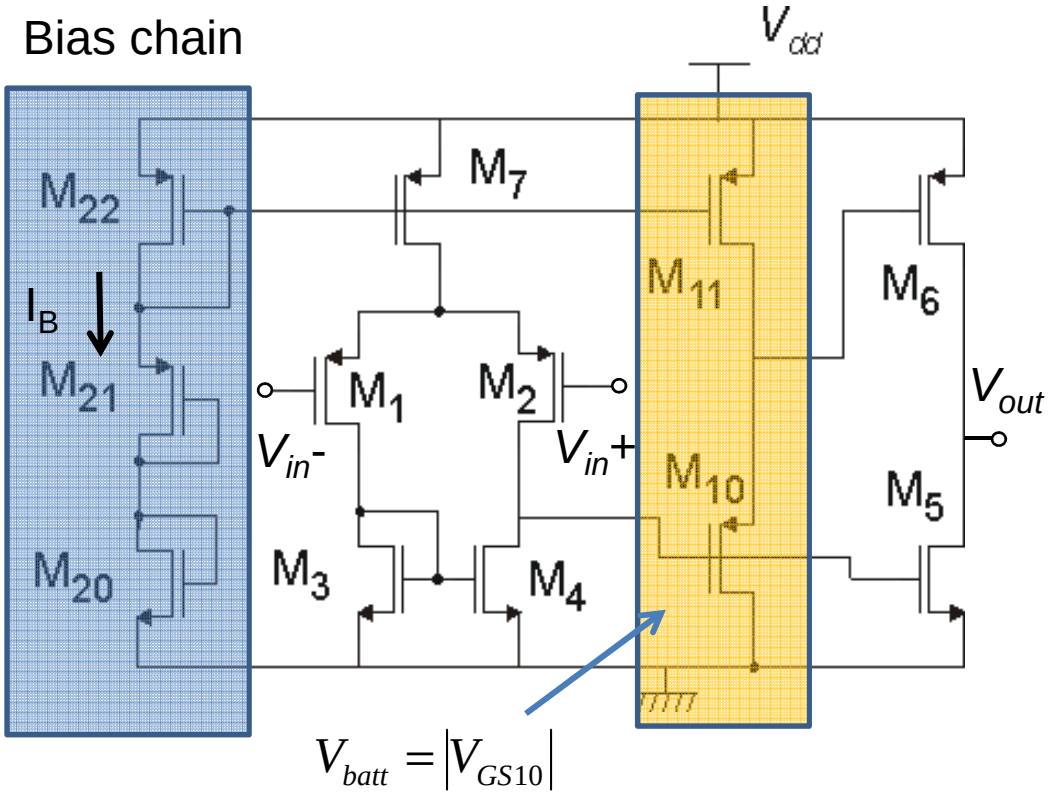
Class - B

$$V_{GS6} = V_{DD} - V_{batt} - V_{GS5}$$

I_{D5} depends only on I_B (bias current), while
I_{D6} depends also on V_{DD}

Very poor PSSR !

Two stage – Class AB Op-Amp
Solution 1: Bias Chain



$$I_{D5} = I_{D3}\frac{\beta_5}{\beta_3} = \frac{I_B}{2}\frac{\beta_7}{\beta_{22}}\frac{\beta_5}{\beta_3}$$

By design:

$$\frac{\beta_{10}}{\beta_{21}} = \frac{\beta_{11}}{\beta_{22}} \Rightarrow V_{GS21} = V_{GS10}$$

$$\frac{\beta_3}{\beta_{20}} = \frac{1}{2}\frac{\beta_7}{\beta_{22}} \Rightarrow V_{GS3} = V_{GS20}$$

$$V_{GS6} = V_{GS22} \qquad I_{D6} = I_B\frac{\beta_6}{\beta_{22}}$$

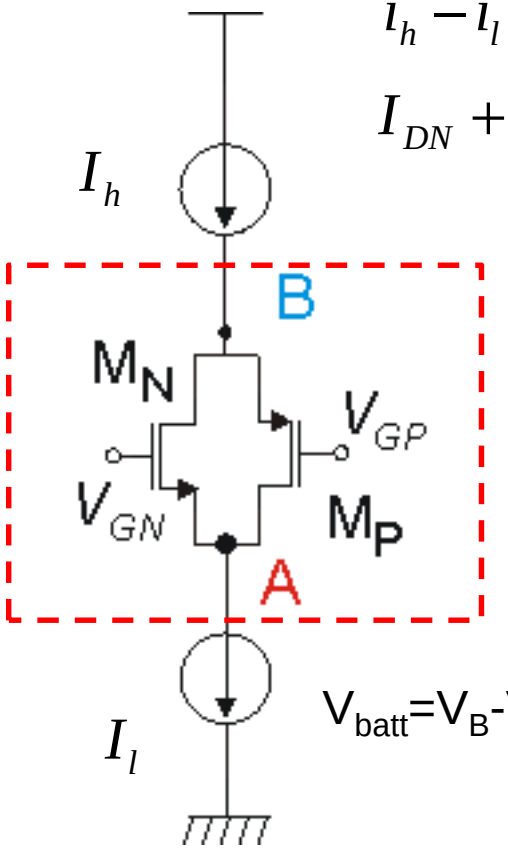
Solves: I_{D5} and I_{D6} matching is now V_{DD} independent

But: Limitations remain on the maximum output V_{GS}

$$V_{GS5MAX} = V_{ic} + |V_{tp}| < V_{DD}$$

$$|V_{GS6}|_{MAX} = V_{DD} - V_{batt} < V_{DD}$$

Solution 2: Floating battery
Head–to-Tail Mesh («Monticelli Cell»)



$$i_h - i_l = G_{m1} v_{id} << I_h,\ I_l$$

$$I_{DN} + I_{DP} = I_h = I_p \cong \text{constant}$$

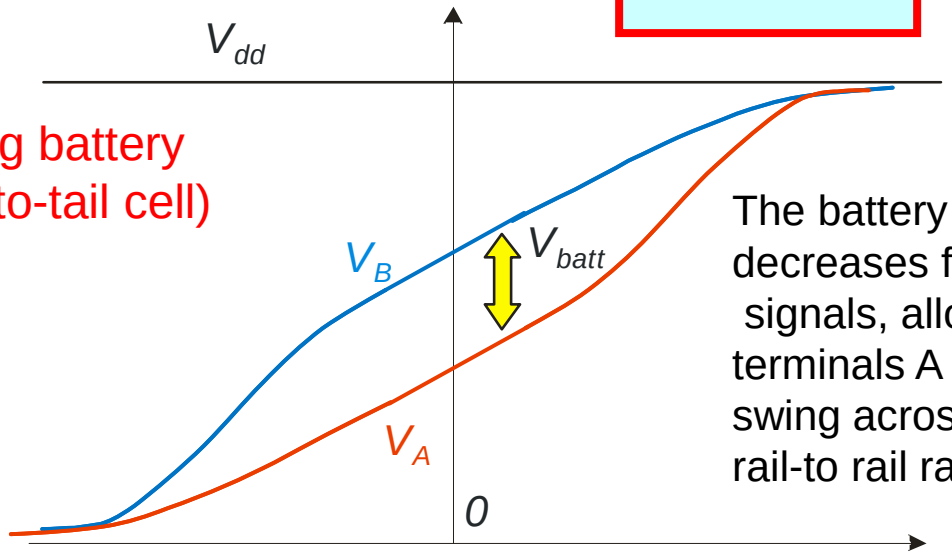
$$i_n + i_p \cong 0$$

$$g_{mn} v_a = g_{mp} v_b$$

$$\frac{v_a}{v_b} = \frac{g_{mp}}{g_{mn}}$$

Floating battery
(head-to-tail cell)

$V_{batt}=V_B-V_A$



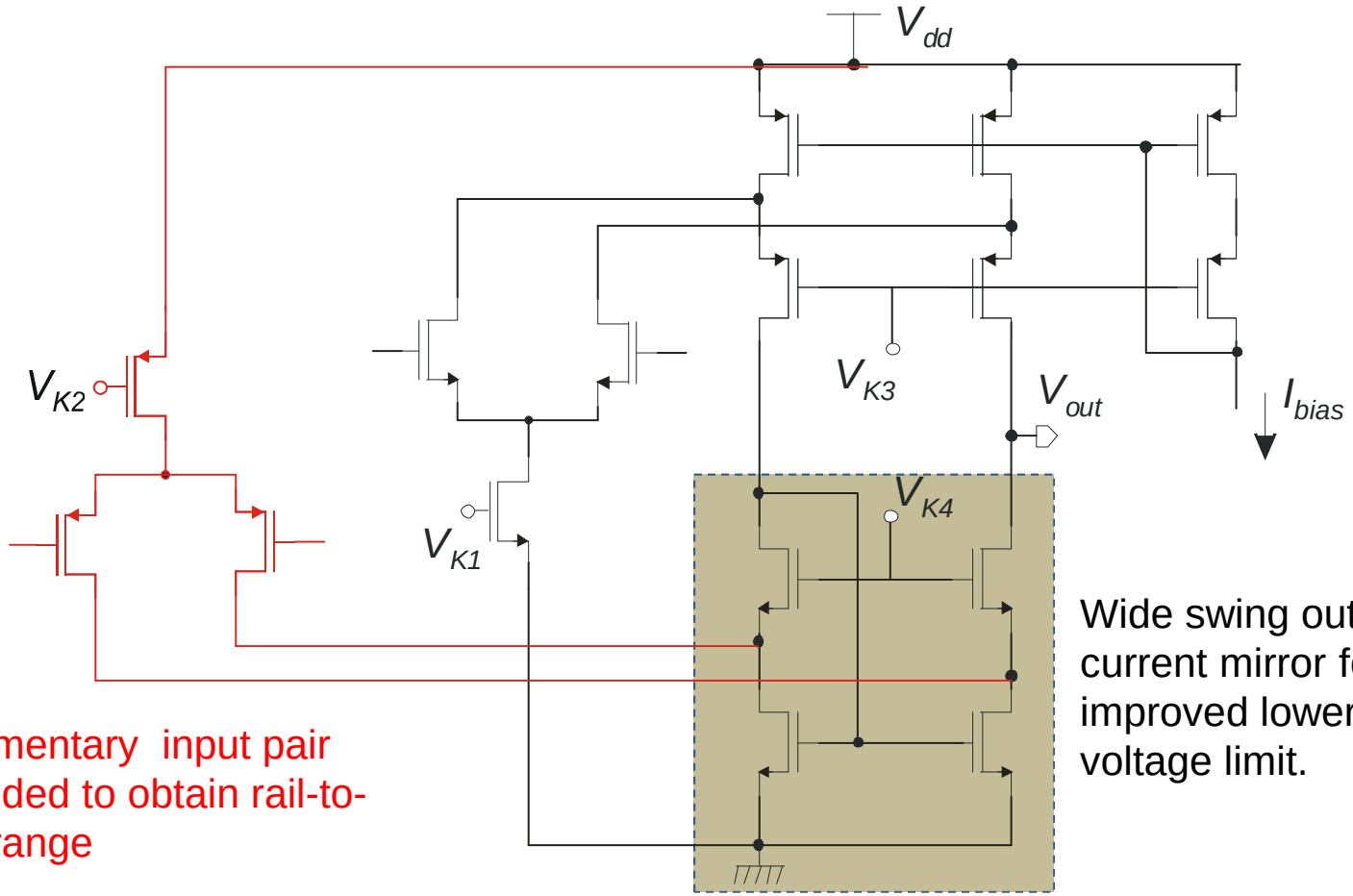
The battery voltage decreases for large signals, allowing terminals A and B to swing across a full rail-to rail range

$$i_h - i_l = G_{m1} v_{id}$$

D. M. Monticelli, “A quad CMOS single-supply op amp with rail-to-rail output swing,” IEEE J. Solid-Stare Cite., vol. SC-21, pp. 1026-1034, Dec. 1986.

First stage with folded cascode topology

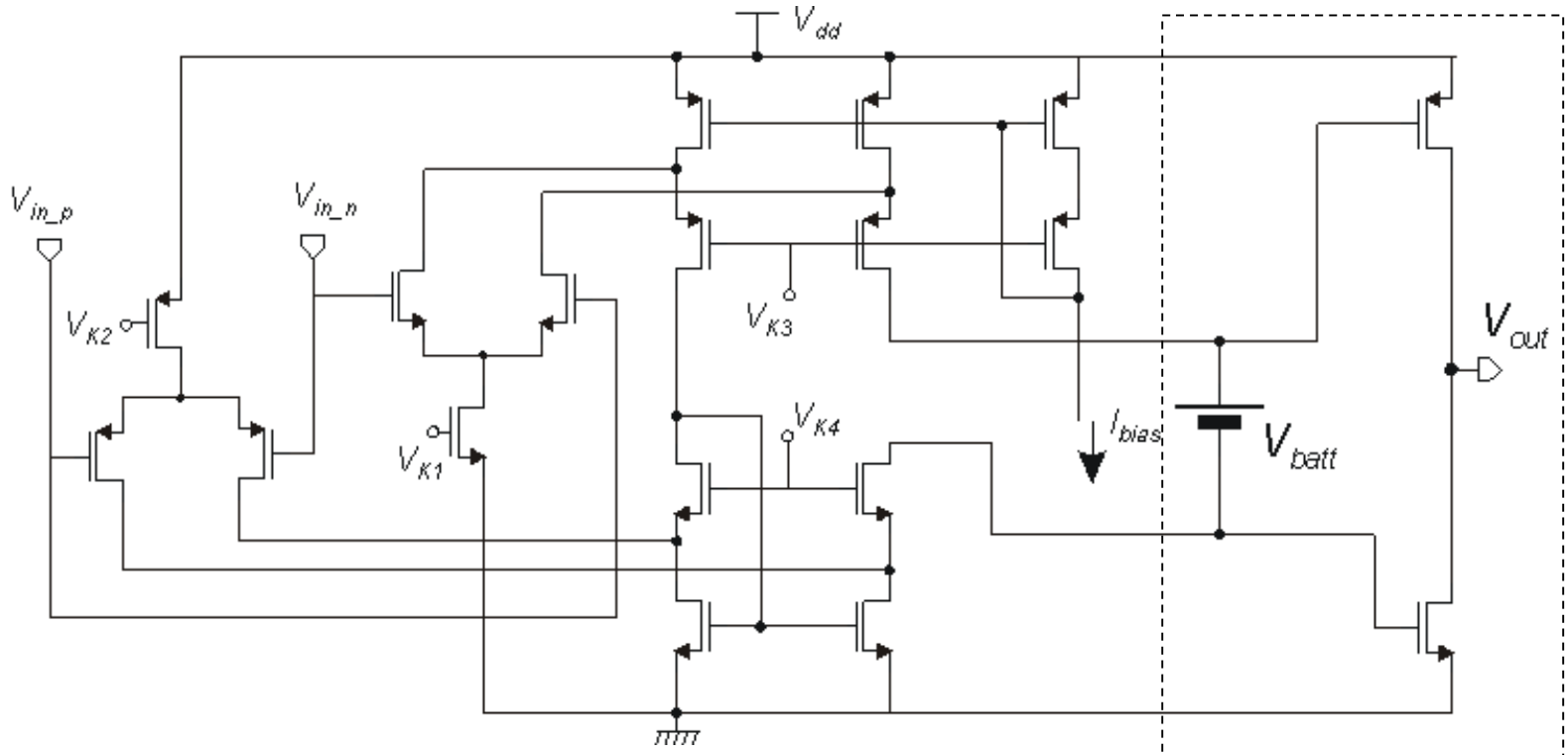
The floating battery class-AB control is often combined with a first stage with folded cascode structure. This stage provides increased gain and can be easily equipped with complementary input pairs to obtain rail-to-rail input range



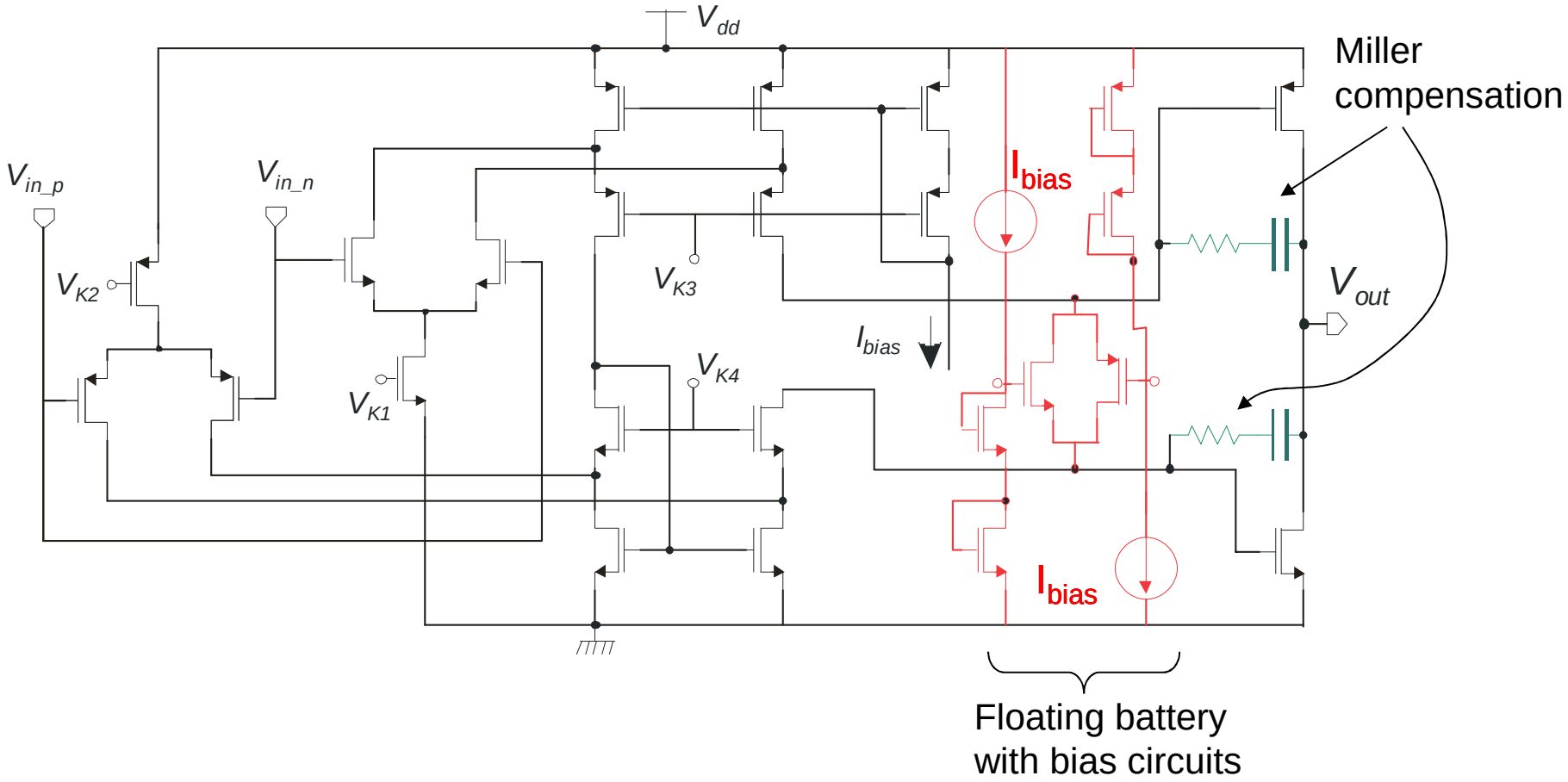
A complementary input pair can be added to obtain rail-to-rail input range

Wide swing output current mirror for improved lower output voltage limit.

Two stage opamp with folded cascode input stage



Two stage opamp with folded cascode input stage and floating battery



R. Hogervorst, J.P. Tero, R. G. H. Eschauzier, and J. H. Huijsing, “A Compact Power-Efficient 3 V CMOS Rail-to-Rail Input/Output Operational Amplifier for VLSI Cell Libraries”, IEEE J. SOLID-STATE CIRCUITS. vol. 29, 1994