Lecture 9
IL2218 Analog electronics, advanced course

- Ch 9 Operational amplifiers
  - One stage OP amps
  - Cascode OP amps, telescopic
  - Design example 9.5
  - Folded Cascode OP amps
  - Design example 9.6
  - Two stage OP amps

Important Parameters

Gain

Input resistance

Output resistance

Small-Signal Bandwidth

Large-Signal Bandwidth

Output Swing

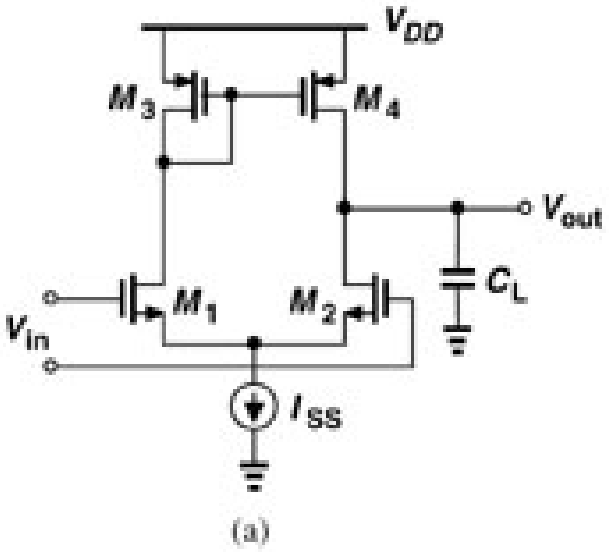
Linearity

Noise and Offset

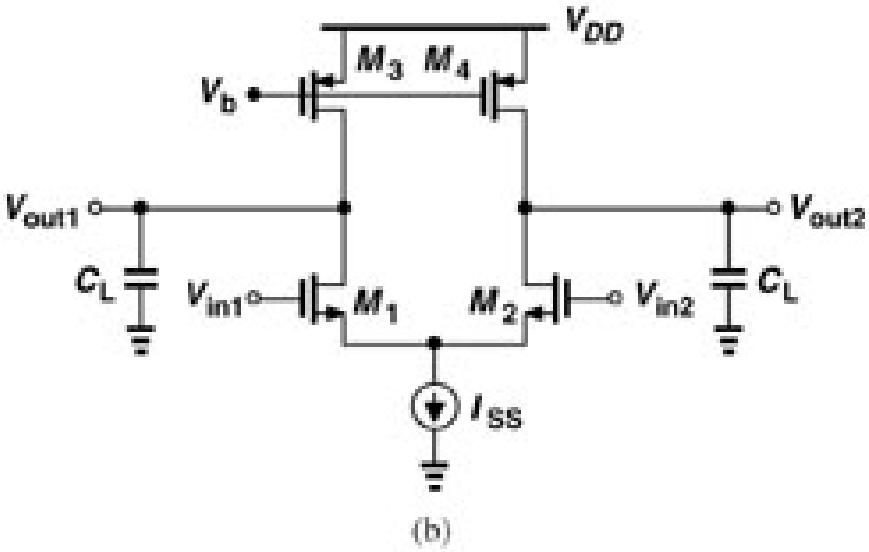
Supply Rejection

One-stage Operational Amplifier

Single ended output



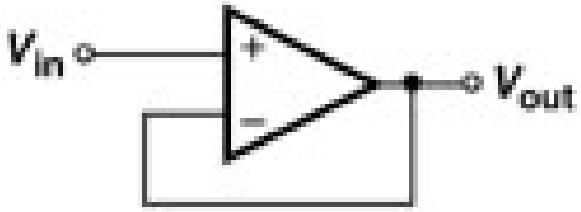
Differential output



$$A_v \approx g_{mN}\left(r_{oN} \;//\; r_{oP}\right)$$

Max gain ≈ 20

One-Stage Op Amp in Unity Gain Configuration



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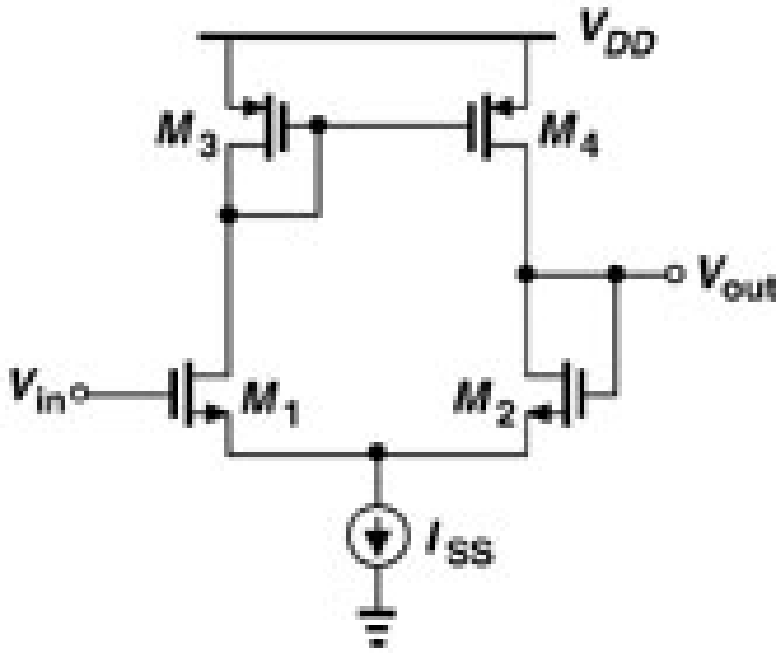
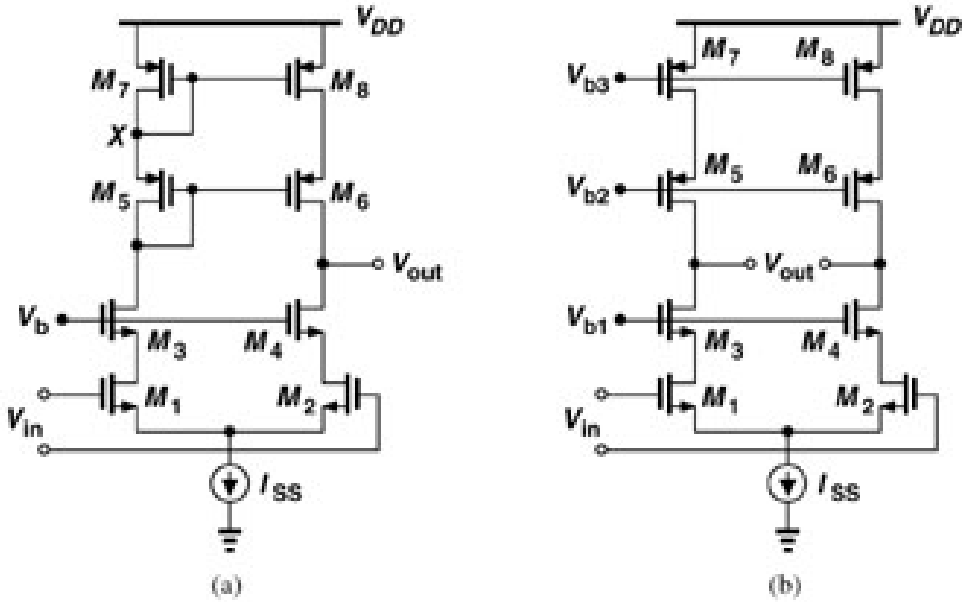


Cascode Op Amps, telescopic

Single ended output

Differential output



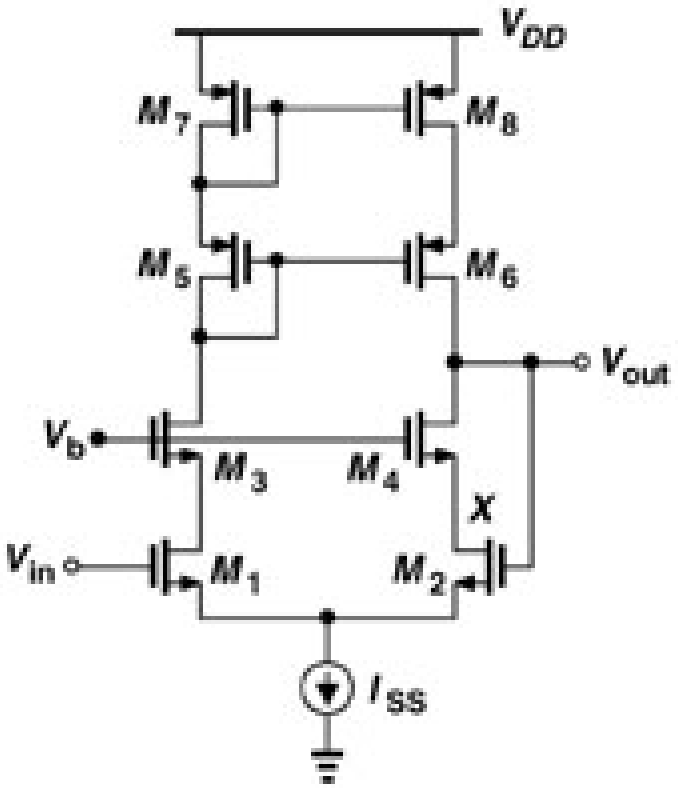
Higher gain

Lower swing

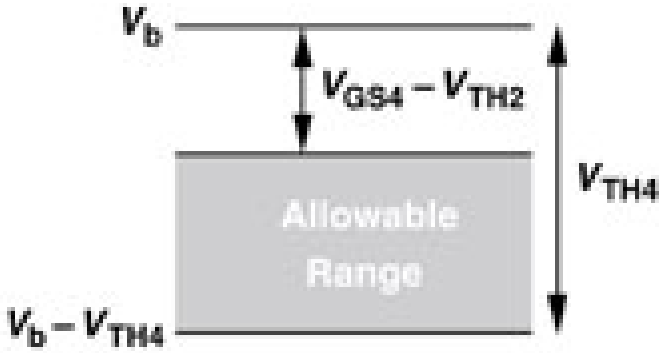
Additional poles

$$A_v \approx g_{mN}\left(g_{mN}r_{oN}^2 \;//\; g_{mP}r_{oP}^2\right)$$

Unity Gain One Stage Cascode



Limited output swing
In unity gain feedback



Example 9.5

Example 9.5

Design a fully differential telescopic op amp with the following specifications: $V_{DD} = 3$ V, differential output swing $= 3$ V, power dissipation $= 10$ mW, voltage gain $= 2000$. Assume $\mu_n C_{ox} = 60\ \mu\text{A/V}^2$, $\mu_p C_{ox} = 30\ \mu\text{A/V}^2$, $\lambda_n = 0.1\ \text{V}^{-1}$, $\lambda_p = 0.2\ \text{V}^{-1}$ (for an effective channel length of $0.5\ \mu$m), $\gamma = 0$, $V_{THN} = |V_{THP}| = 0.7$ V.

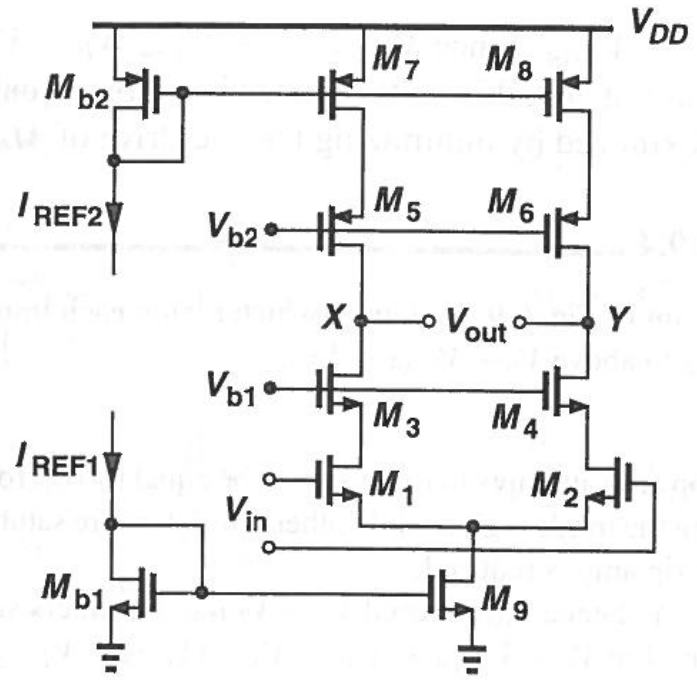
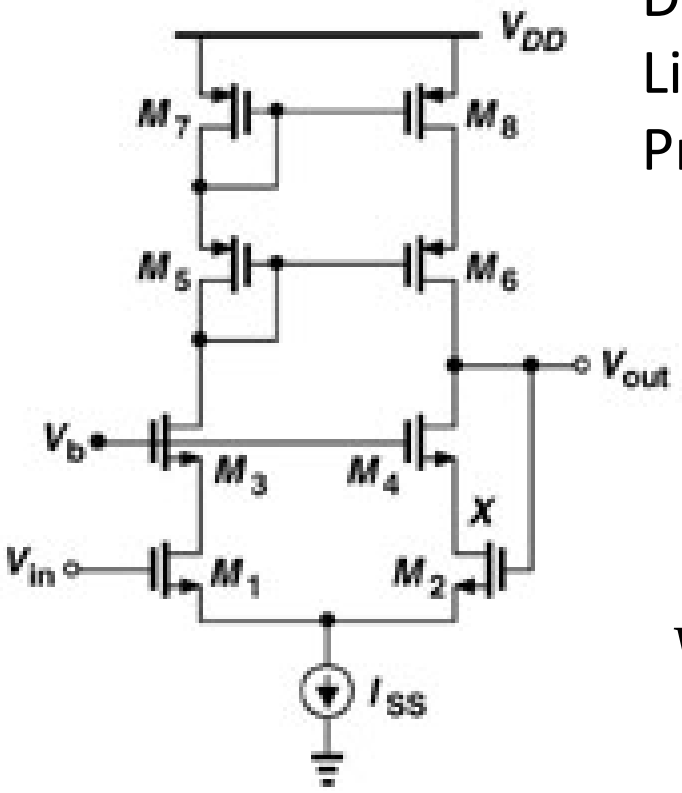


Figure 9.10

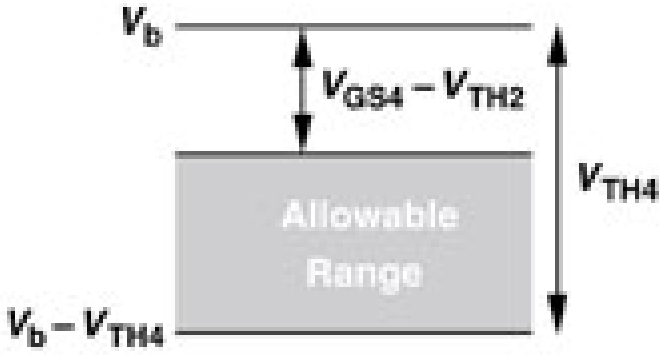
Telescopic Cascode Op Amps



Drawbacks:

Limited output swing

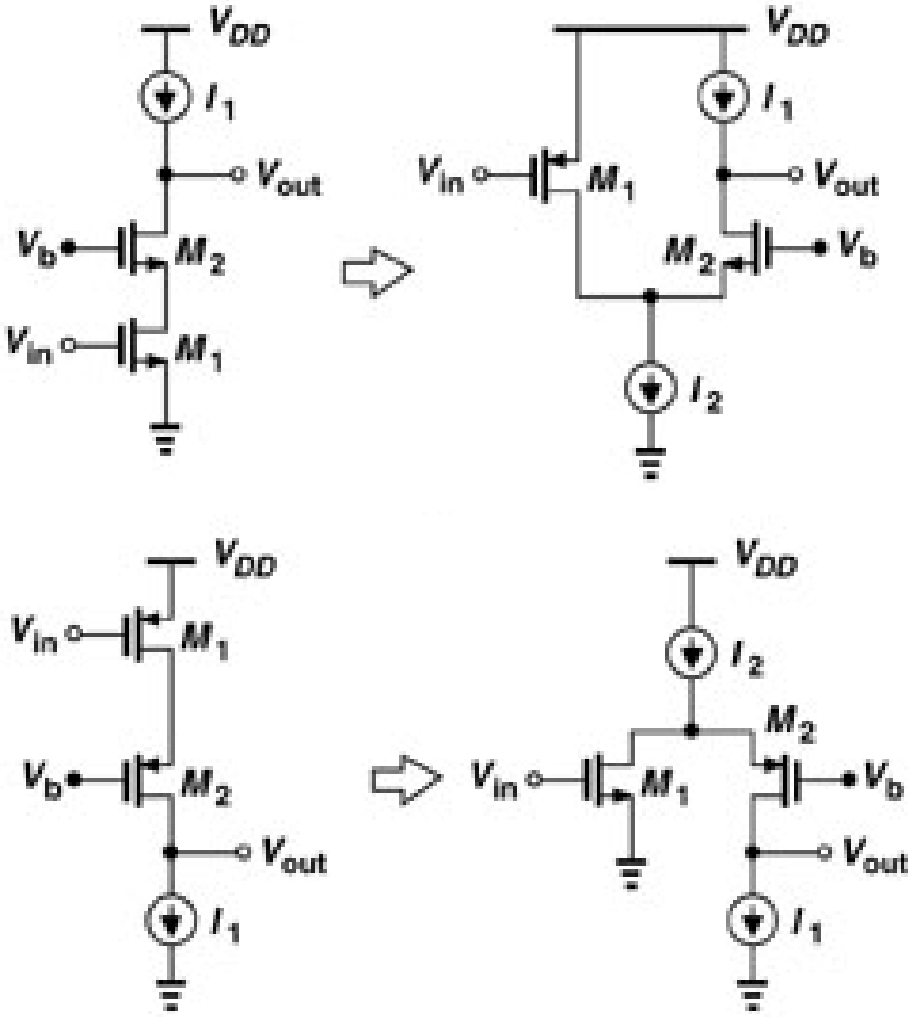
Problem to short input and output



$$V_{\max} - V_{\min} = V_{TH4} - (V_{GS4} - V_{TH2})$$

Maximized by minimizing the overdrive of M_4, but always less than V_{TH2}

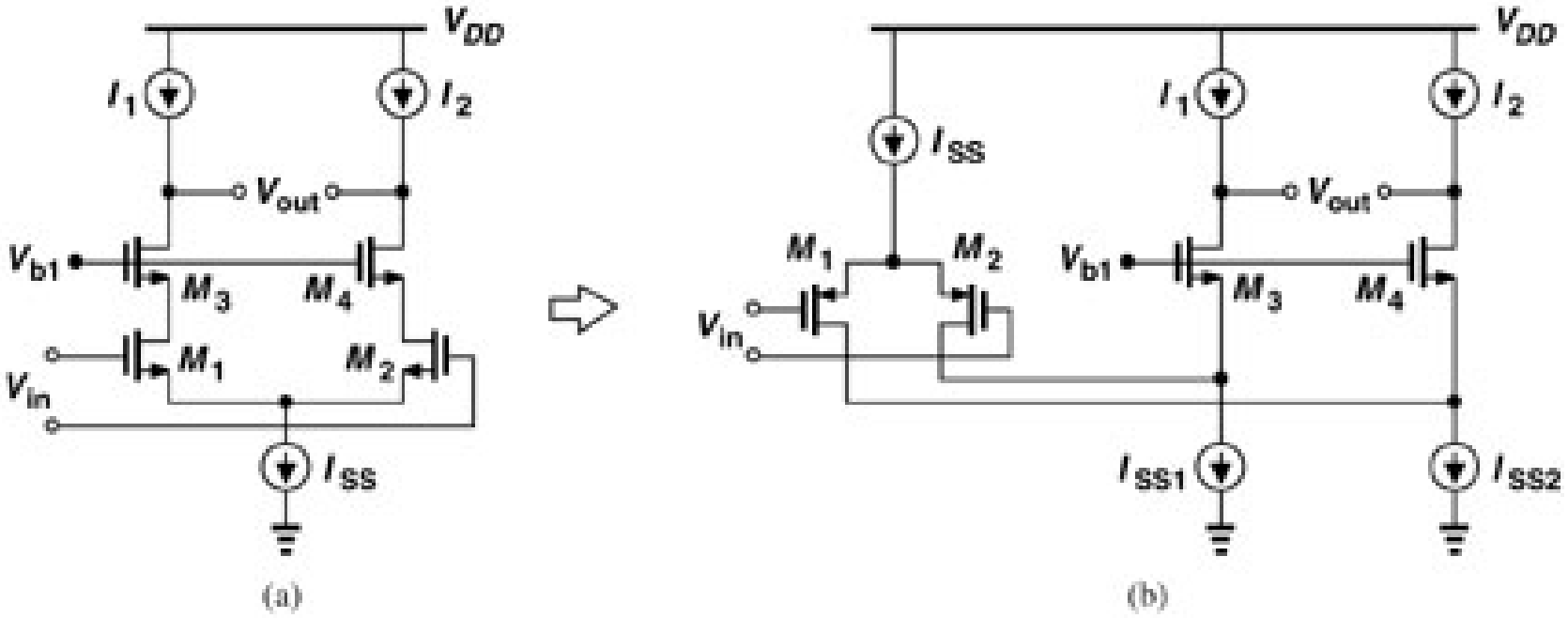
Folded Cascode Amplifier



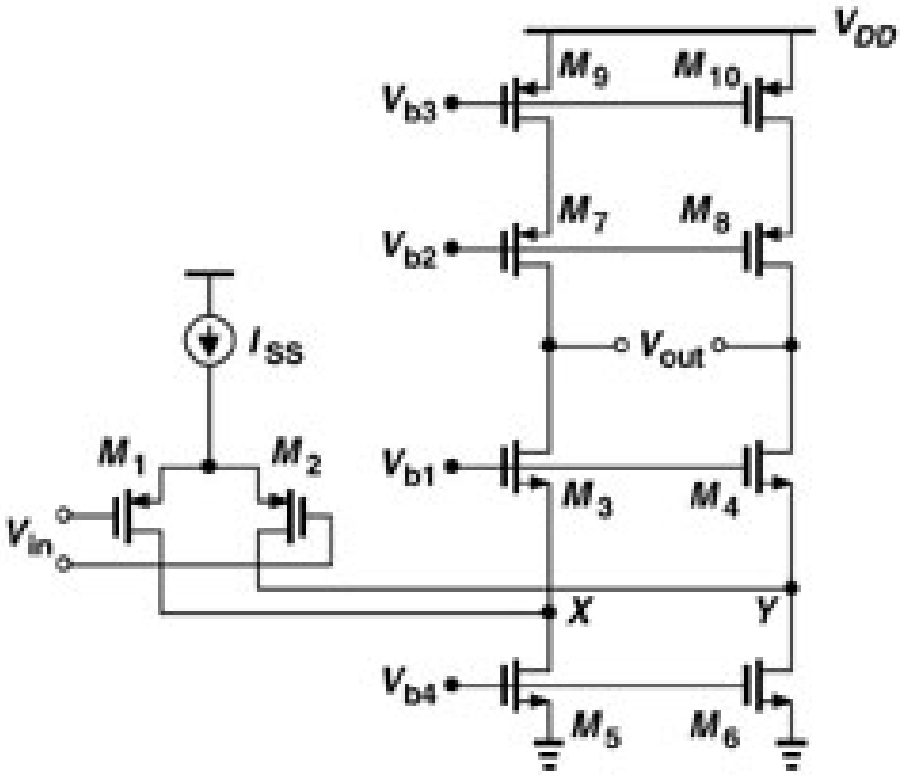
The small signal current generated by M_1 flows through M_2 and the load

$$A_v \approx g_{m1} R_{out}$$

Folded Cascode Op Amps



Folded Cascode Op Amps



Why, so many transistors?

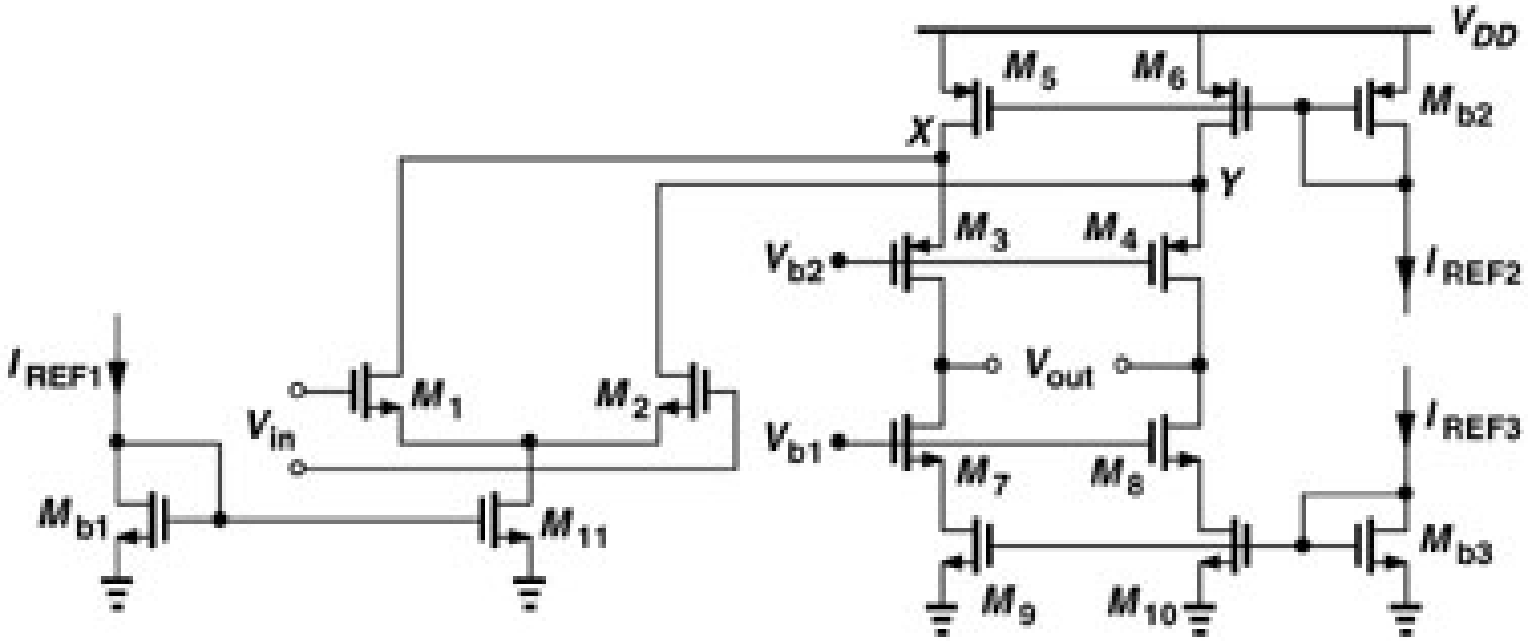
Swing

Lower end $V_{OD3} + V_{OD5}$

Upper end $V_{DD} - \left(|V_{OD7}| + |V_{OD9}|\right)$

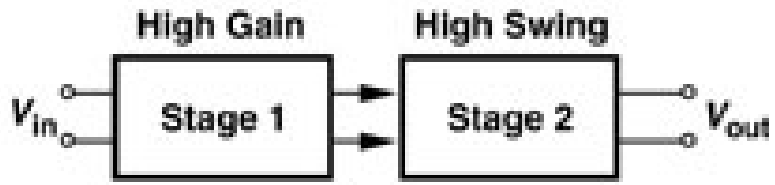
$$|A_v| \approx g_{m1}\{[(g_{m3}+g_{mb3})r_{o3}(r_{o1} \| r_{o5})] // [(g_{m7}+g_{mb7})r_{o7}r_{o9}]\}$$

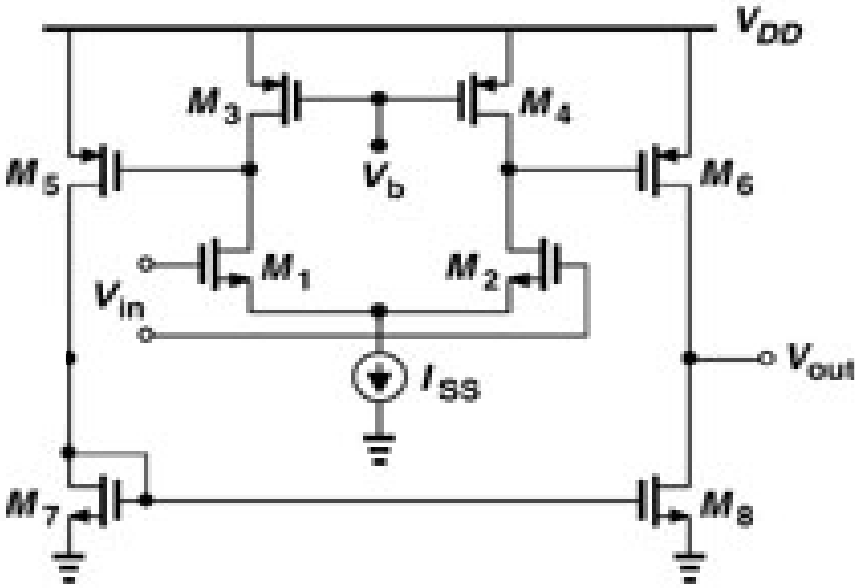
Design example 9.6



Study the example, compare with example 9.5!

Two-Stage Op Amps



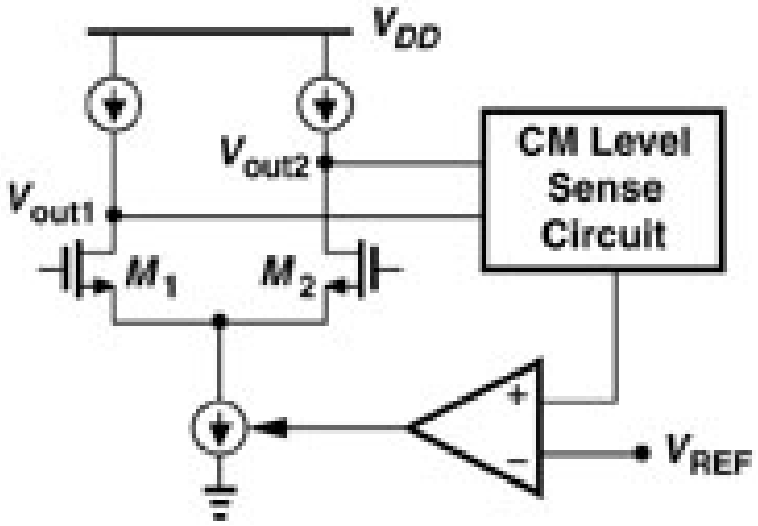


Gain= ?

Common Mode Feedback

In high gain amplifiers, we wish a *p*-type current source to balance a *n*-type current source.

Mismatches can drive *p*-type or *n*-type current source into triode region.



If the output CM level requires calculation on device properties, then it is poorly defined.