جامعة القاهرة

Analog Integrated Circuits Lecture 2: Common-Mode Feedback Circuits

ELCN467 – Spring 2014

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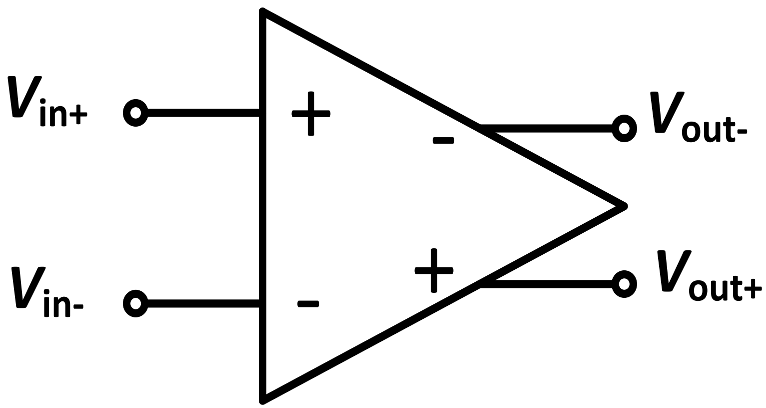
Introduction

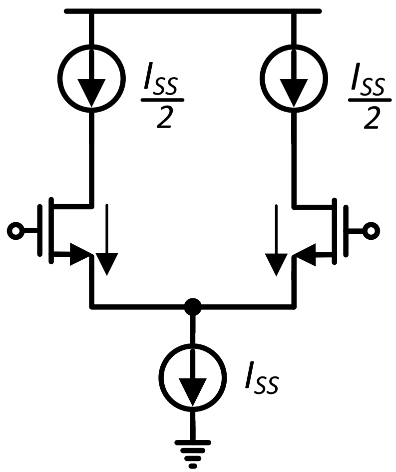


- Fully differential opamp is an opamp where the output is a differential signal as well.

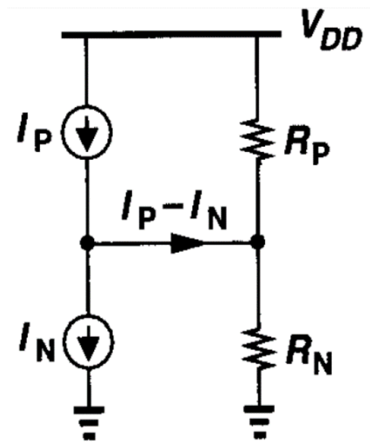
- V_{out+} *and* V_{out-} must be referred to a common-mode level (V_{ocm}).

Fully Differential

Output Common-Mode Level



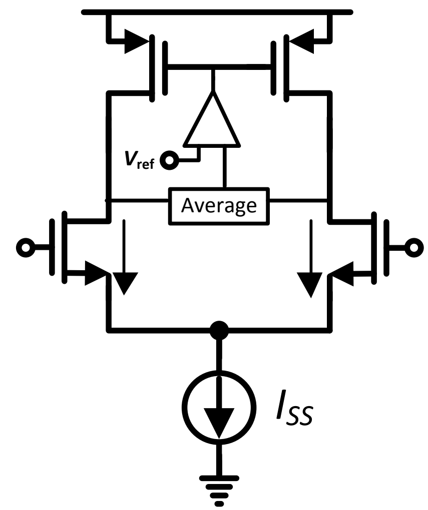
Half Circuit Can be modeled as

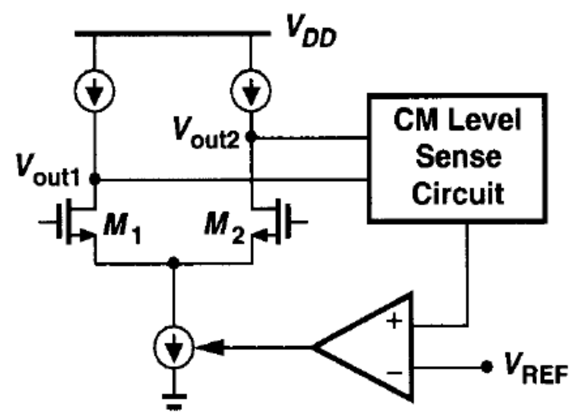


- Two fighting sets of current sources.
- Outputs are floating points (= high-impedance points) → DC-level is not defined in this circuit.
- We must adaptively adjust either the pull-up or the pull-down currents until both match → Output level in the middle.
- Feedback is used to detect the output CM level and adjust one of the two current sources. This Feedback must not corrupt the differential signal.

How to define the output's common mode?

- Circuits needed:
  - Common-mode sensing ≡ Averaging circuit
  - Comparator
- Average operation monitors the bias point but rejects the differential signal.
- $V_{ref} = V_{desired} \cong \frac{V_{DD}}{2}$, **This is only possible if currents match** $\Longrightarrow I_P = I_N$



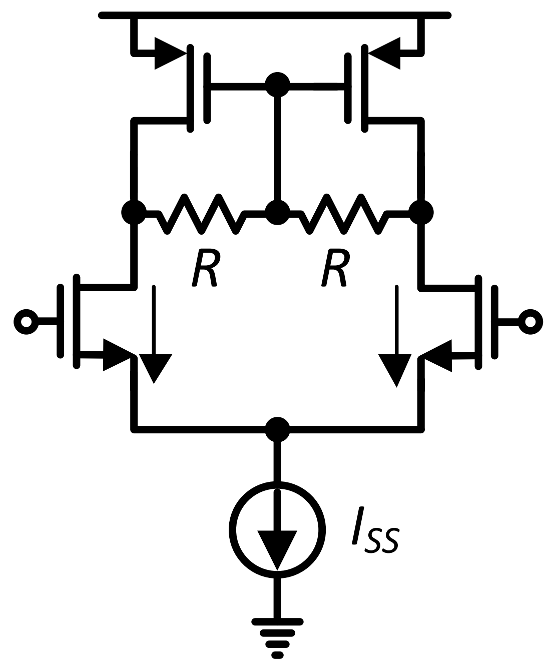


Common-Mode Feedback Circuit – Example 1

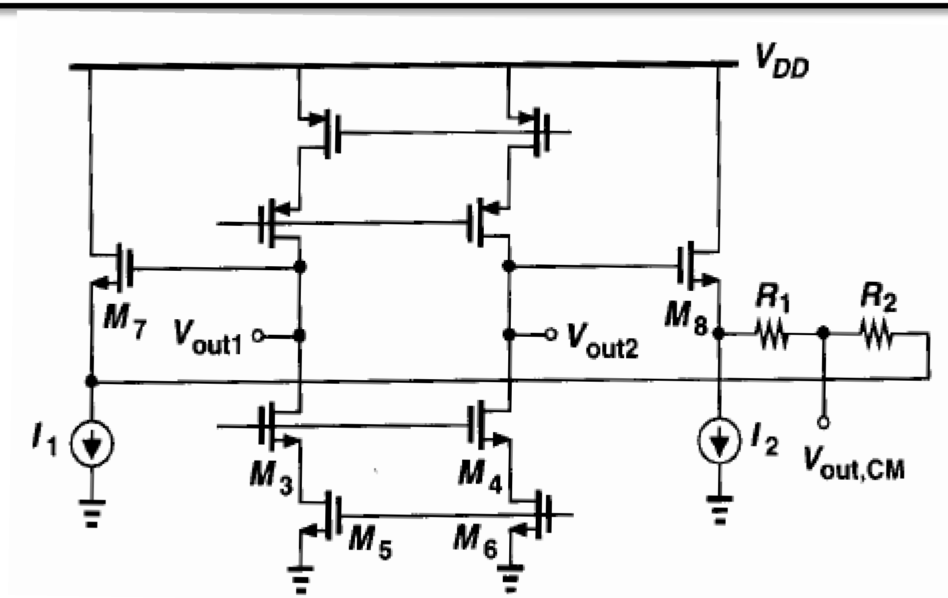
- The feedback is called : Common-Mode feedback "CMFB"

- $V_{outCM} = V_{DD} - |V_{GSp}|$
  $= V_{DD} - (|V_{THp}| + |V_{eff}|)$

- Drawbacks:
  - Swing is limited to $\pm|V_{THp}|$
  - Resistors are used in sensing the common mode, which load the differential signal and hence lower the gain. Problem is more obvious when output stage is a cascode stage.

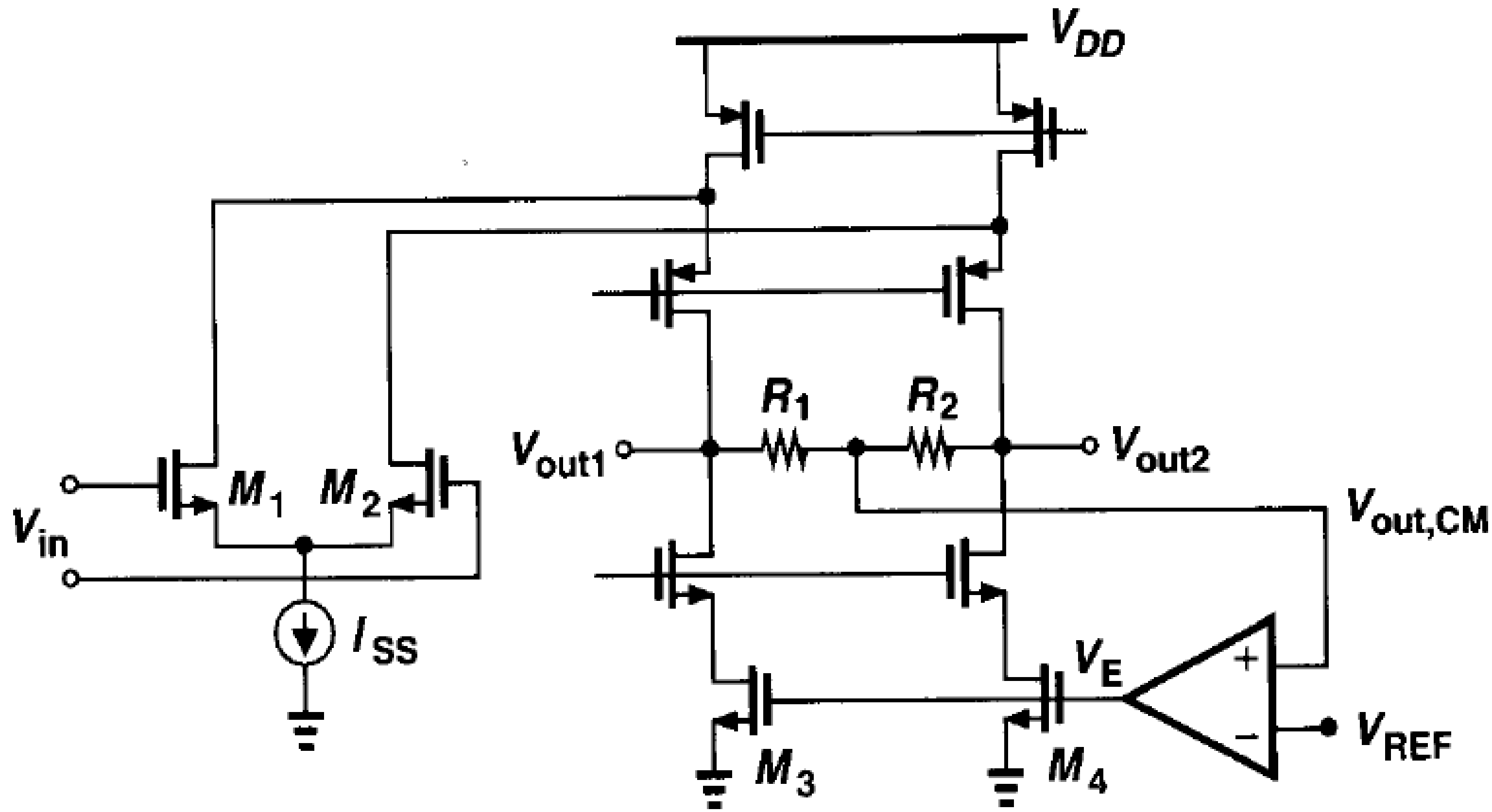


Common-Mode Feedback Circuit – Example 1 - Modified



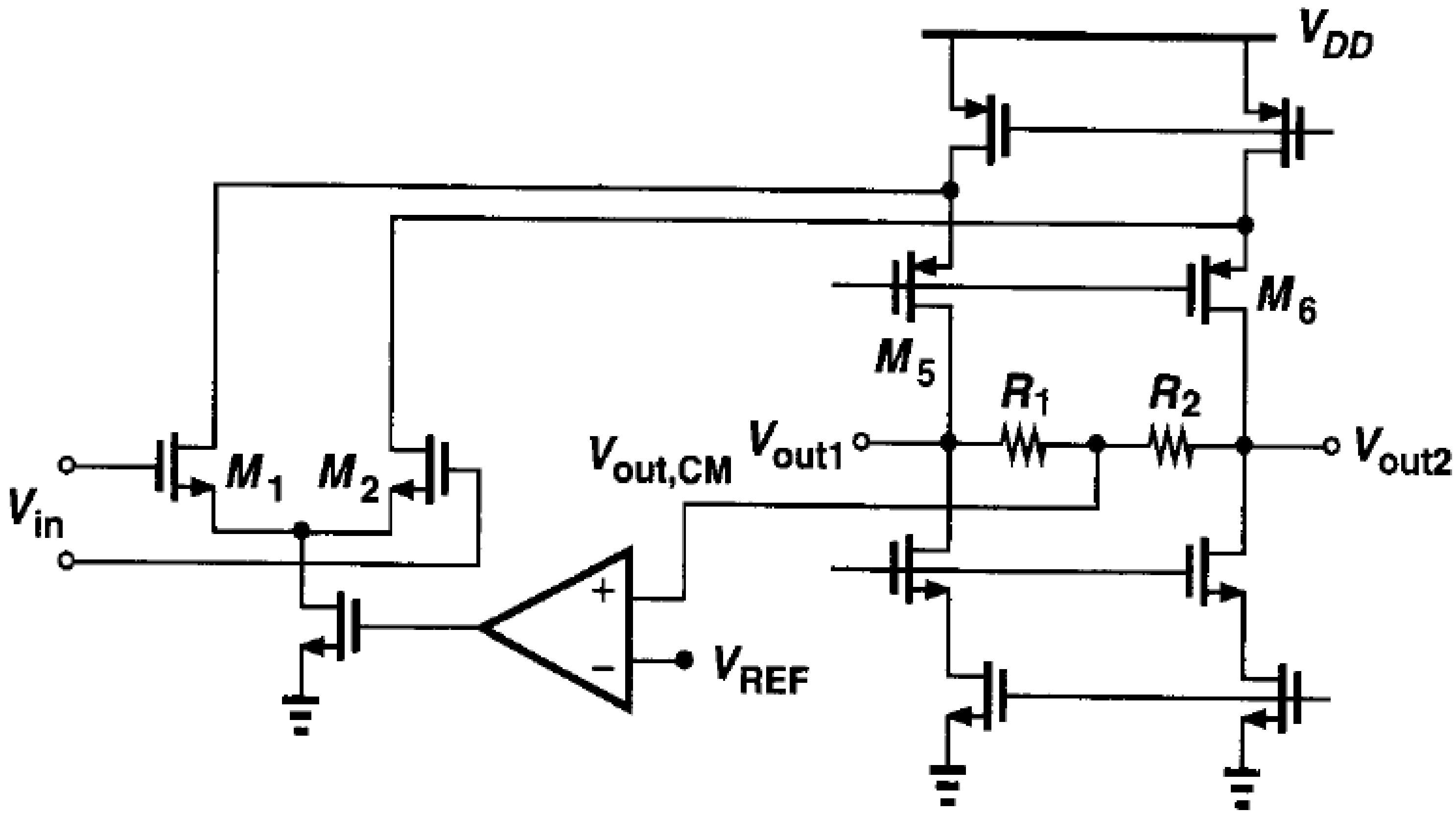
- In order to avoid output loading, Source followers can be used to isolate between the output stage and the sensing circuit.
- $V_{out,CM}$ is the a representation of the output common mode but not the exact one.
- $V_{out,CM} = \frac{V_{out1}+V_{out2}}{2} - V_{GS,SF}$
- $V_{GS,SF}$ is a fixed value because $I_1 = I_2$ = constant.

Common-Mode Feedback Circuit – Example 2A



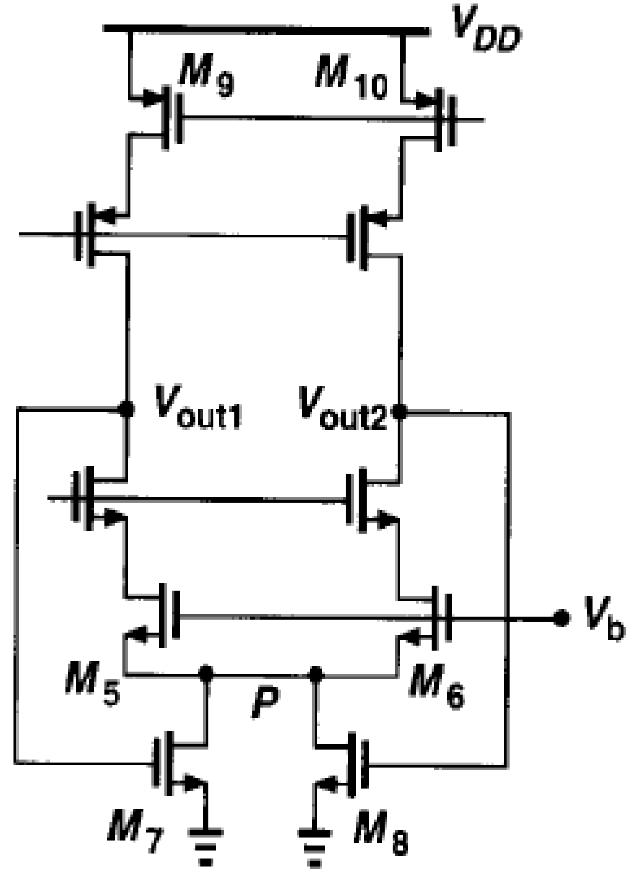
- What is the problem with this architecture?

Common-Mode Feedback Circuit – Example 2B



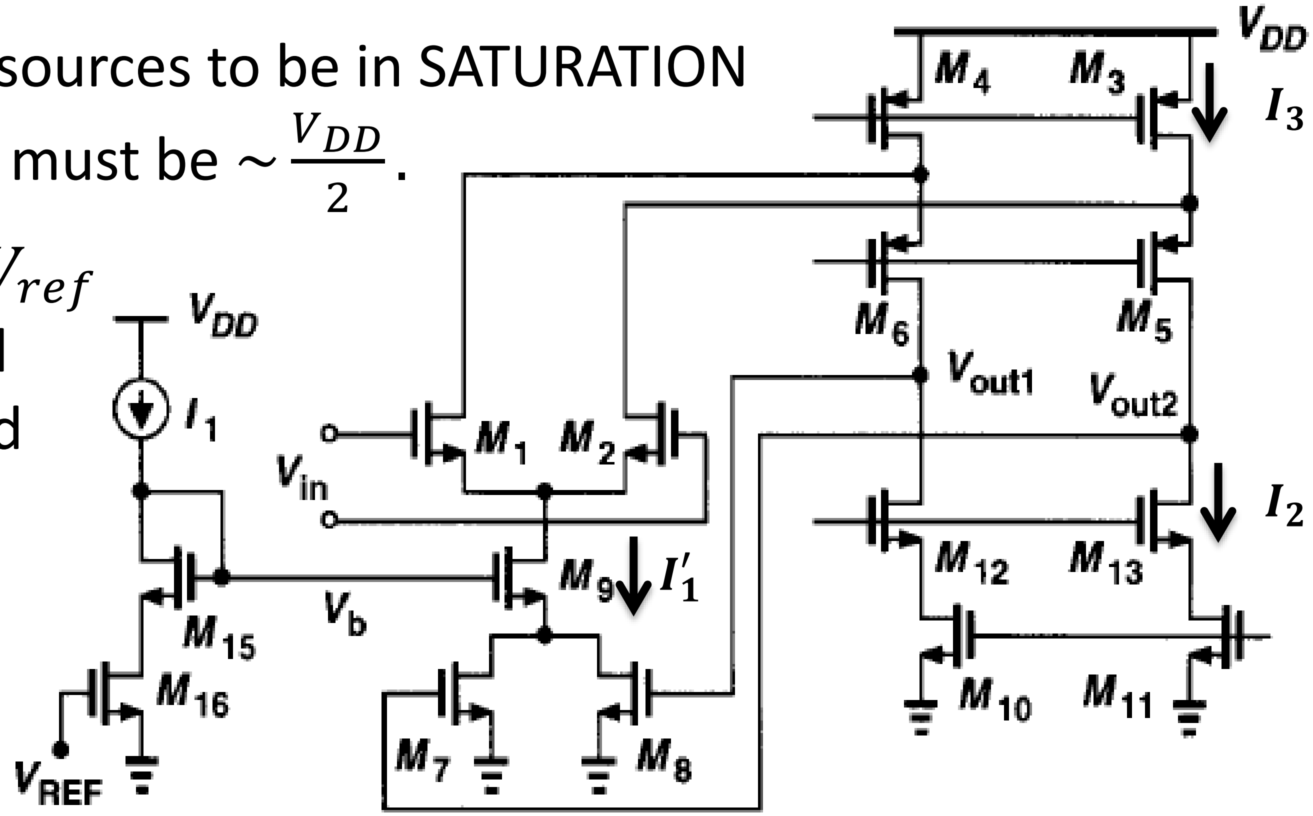
Common-Mode Feedback Circuit – Example 3

- Output bias is set by the V_{GS} of the pull down FETs.
- Since, optimum bias $\sim \frac{\mathrm{V_{DD}}}{2} \rightarrow$ The pull-down current sources are biased in **triode**.
- What about CMRR?
  - The feedback across the NMOS pull-down devices, improves the current source resistance (in closed loop) → high CMRR.
  - But speed is not high, MOS transistors in triode have low f_T → Can't correct high speed common-mode variations.
- Drawbacks:
  - Output common mode is not well defined and is a function of the device parameters.
  - Current source devices (triode) are usually huge.
  - Swing is limited to guarantee both transistors are in triode.

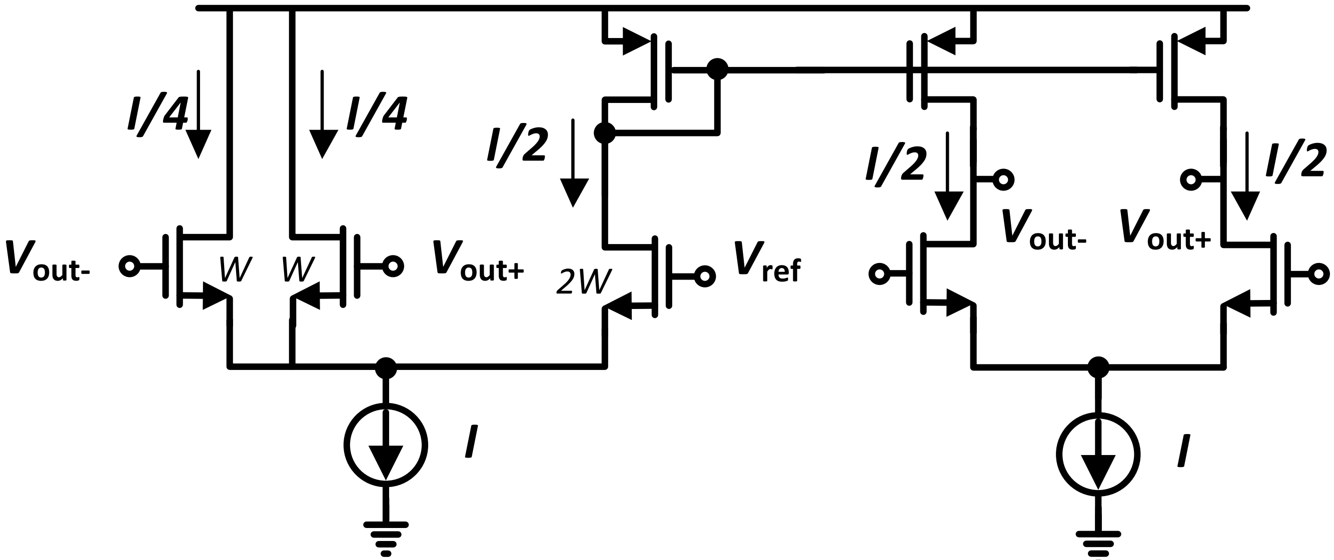


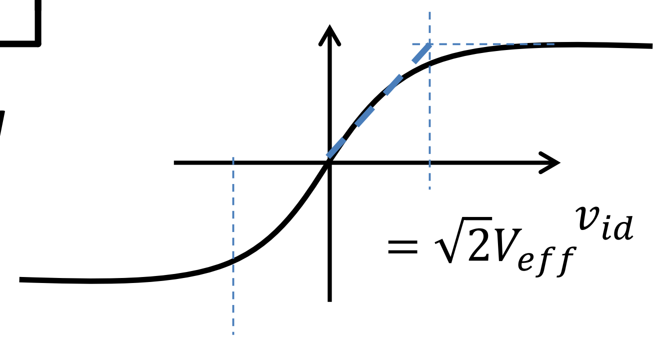
Common-Mode Feedback Circuit – Example 3 - Modified

- If $M_9 = M_{15}$ and $M_{16} = M_7 + M_8$
  $\rightarrow I_1 = I_1'$ only if $V_{outCM} = V_{ref}$
- $I_3 = I_1'/2 + I_2$
- For all current sources to be in SATURATION region, V_{outCM} must be $\sim \frac{V_{DD}}{2}$.
- We set I_1 and V_{ref} For the desired values of I_1' and V_{outCM}.



Common-Mode Feedback Circuit – Example 4: Preferred Solution





- CM loop gain = $\frac{1}{2} g_{m(CMFB)}(r_{oN}//r_{oP})$ (Check)
- CM sensing circuit rejects differential signals as long as the sensing diff. pair remains linear (out of clipping)
- Choose V_{eff} of sensing FETS large enough to sustain largest possible output swing. $(v_{id} = V_{out1} - V_{out2})$
- What can we do to support a larger output swing?
  - Use a separate averaging circuit.

Homework #2

- For all CMFB architectures in this lecture,
  - find the common-mode feedback circuit loop gain,
  - Allowable output swing for proper operation,
  - CMFB loop stability requirements
  - GBW of the CMFB loop

- Convert the opamp you designed in Assignment 3 in ELC401A to a fully differential one and use a CMFB to set the $CM_{out} = \frac{V_{DD}}{2}$.

Review

- Important Specifications:
  - ✓ Differential DC gain
  - ✓ Common-Mode DC gain
  - ✓ GBW
  - ✓ Slew rate
  - ✓ Output common-mode range (available output swing)
  - ✓ Input common-mode range
  - ✓ Common-mode feedback loop gain
  - ✓ Power consumption
  - ○ Input referred noise
  - ○ Input referred offset