ECEN474: (Analog) VLSI Circuit Design
Fall 2012

Lecture 18: OTA CMFB Examples

Sam Palermo

Analog & Mixed-Signal Center

Texas A&M University

Announcements

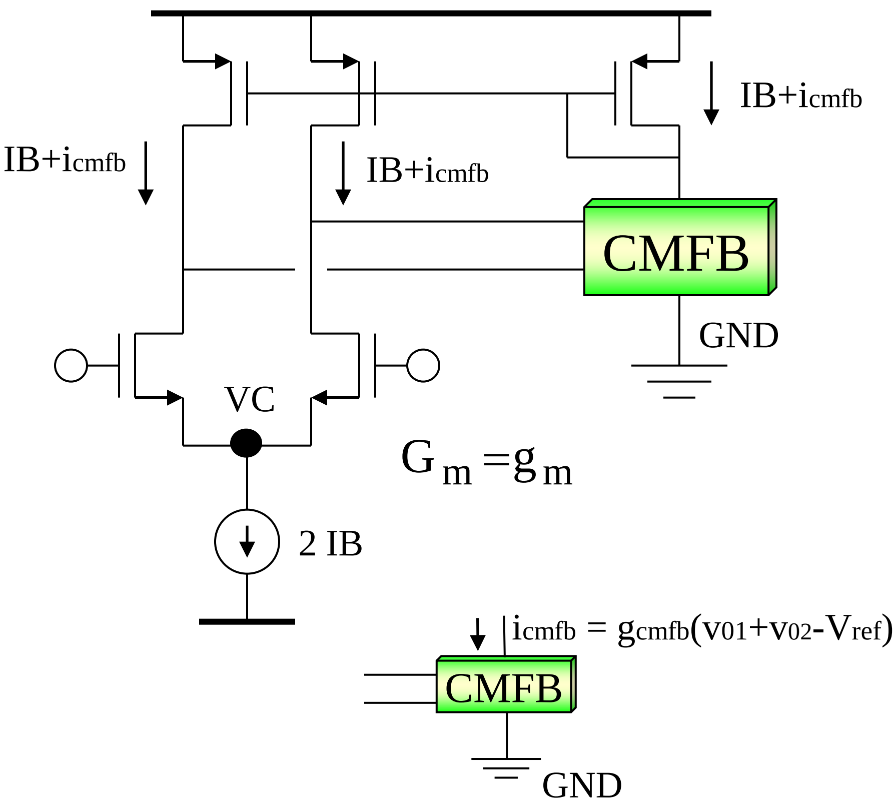
- No class on Monday
- Preliminary report still due Monday (11/19)
  - If you are doing anything not on the list, give me a brief description as soon as possible
- We will have class on Wednesday (11/21)
- Project Extra Credit
  - Potential for 20% extra credit if you layout a key block
  - Report on Dec. 4 doesn't have to have layout
  - For extra credit, an updated report can be turned in during the presentation time (Dec. 10) with layout results
    - The post-layout performance is the only thing that will be considered relative to the original report, i.e. no major circuit changes from the original report

Agenda

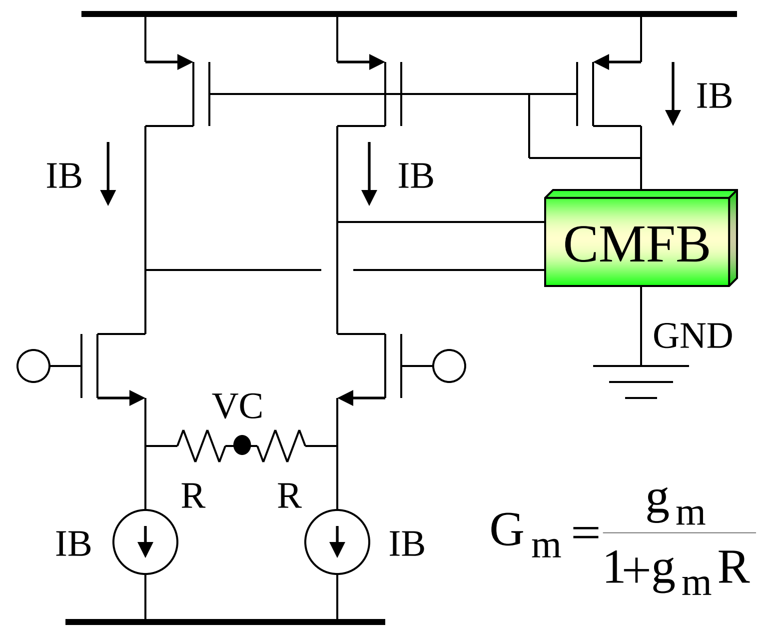
- Multi-OTA stages CMFB
- OTA-C filter w/ CMFB example

CMFB is required for Differential Structures

CMFB Requirements: Fixes the OTA output (low offset) ==> High dc loop gain
Reduction of common-mode noise==> Large Bandwidth

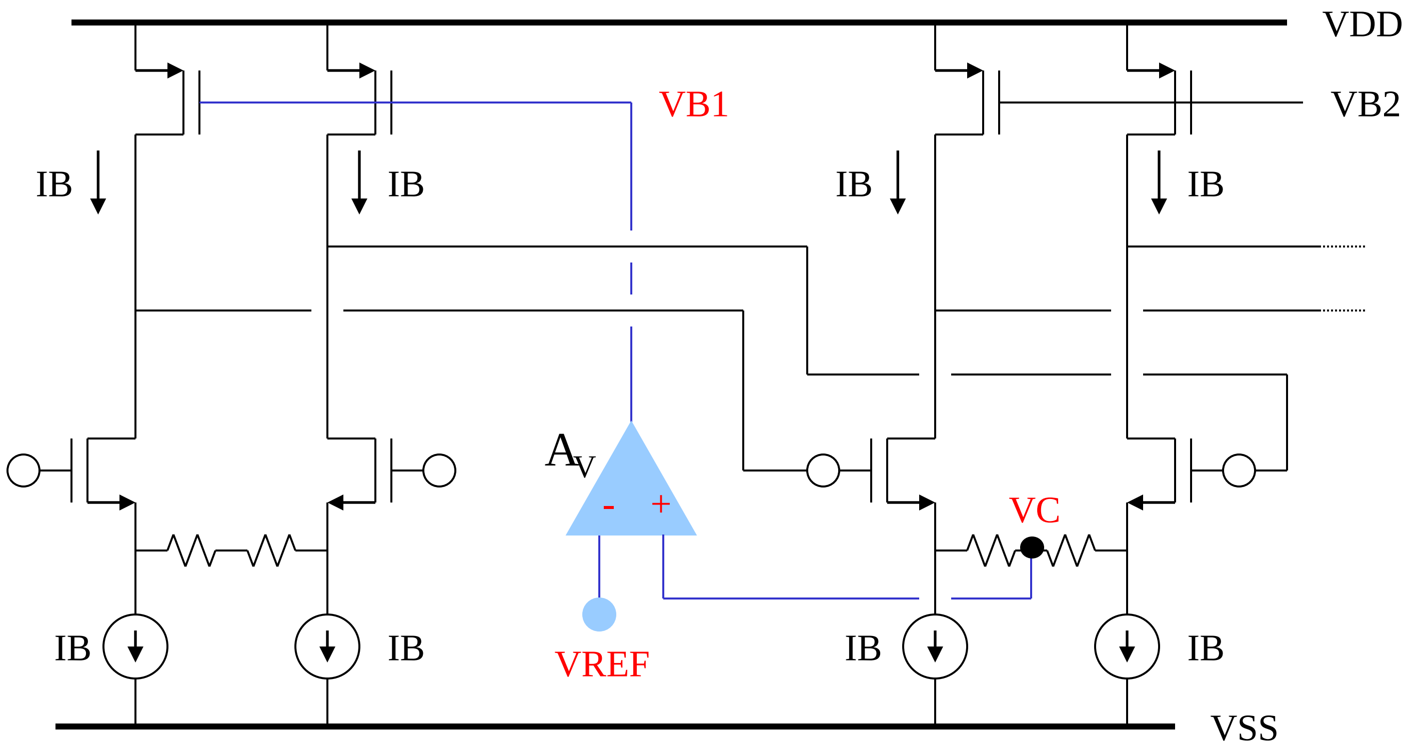


$$G_m = g_m$$



$$G_m = \frac{g_m}{1+g_m R}$$

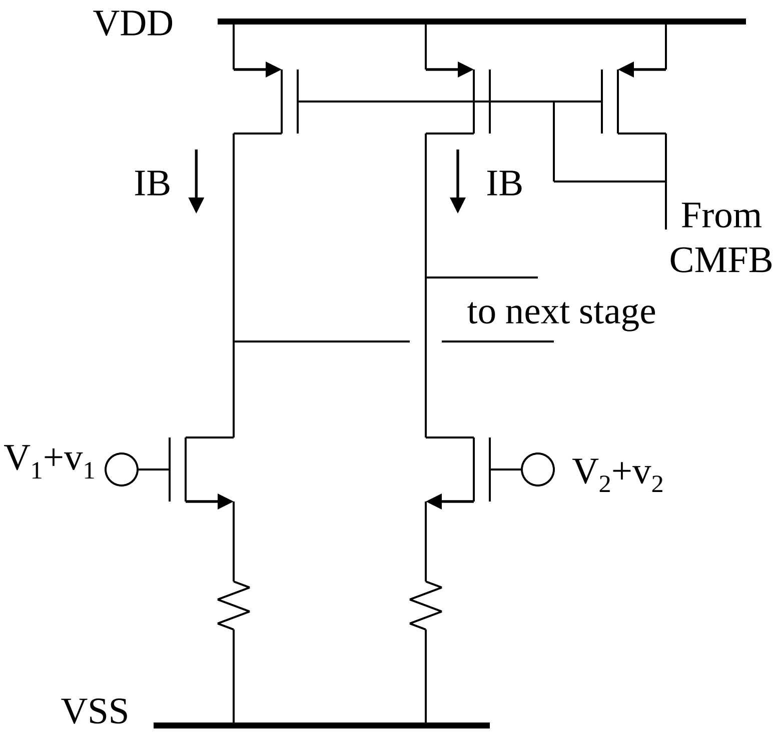
Efficient CMFB for Differential Pair Based OTAs



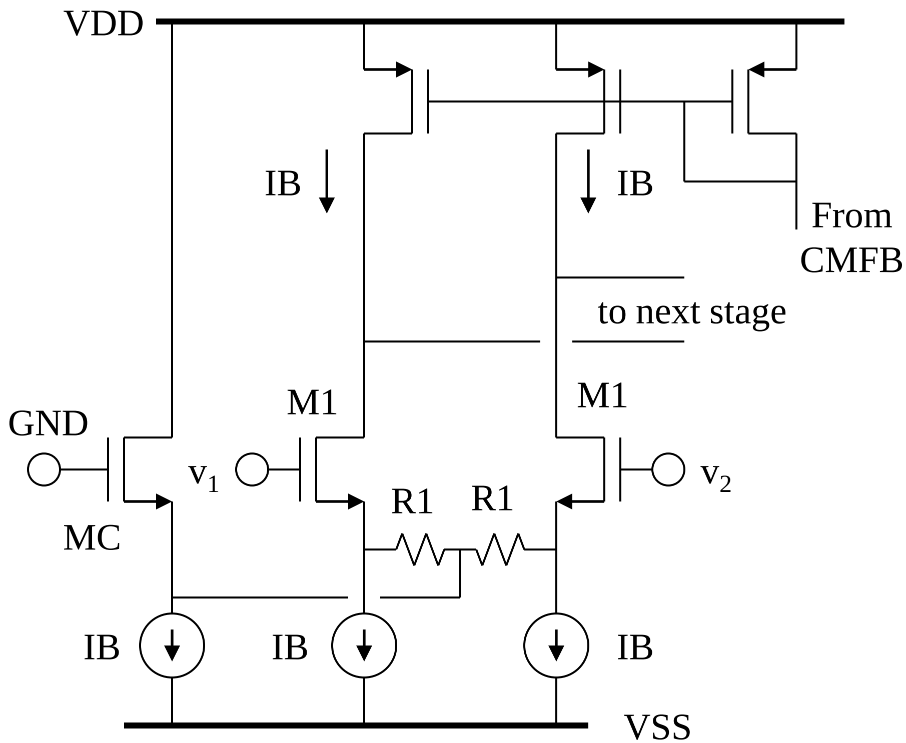
Common-mode loop gain = $A_V\, Gm_p\, R_L$

3 poles in the CMFB loop. Loop stability requires $A_V\, Gm_p / C_L < \omega_{p2}$ @ VC, ω_{p3} @ VB1

Pseudo-Differential OTAs with Source Degeneration

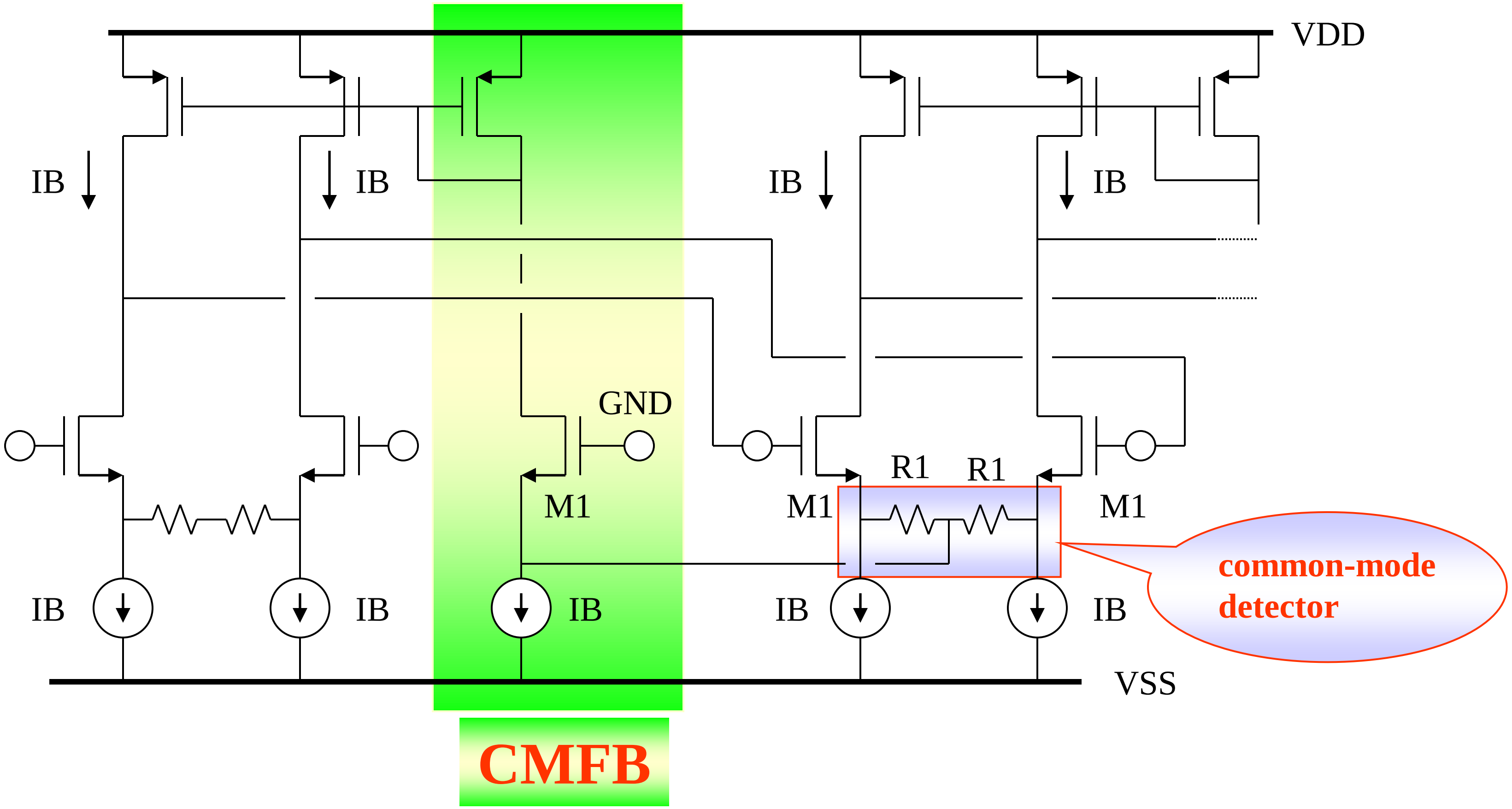


Sensitive to supply noise and common-mode input signals

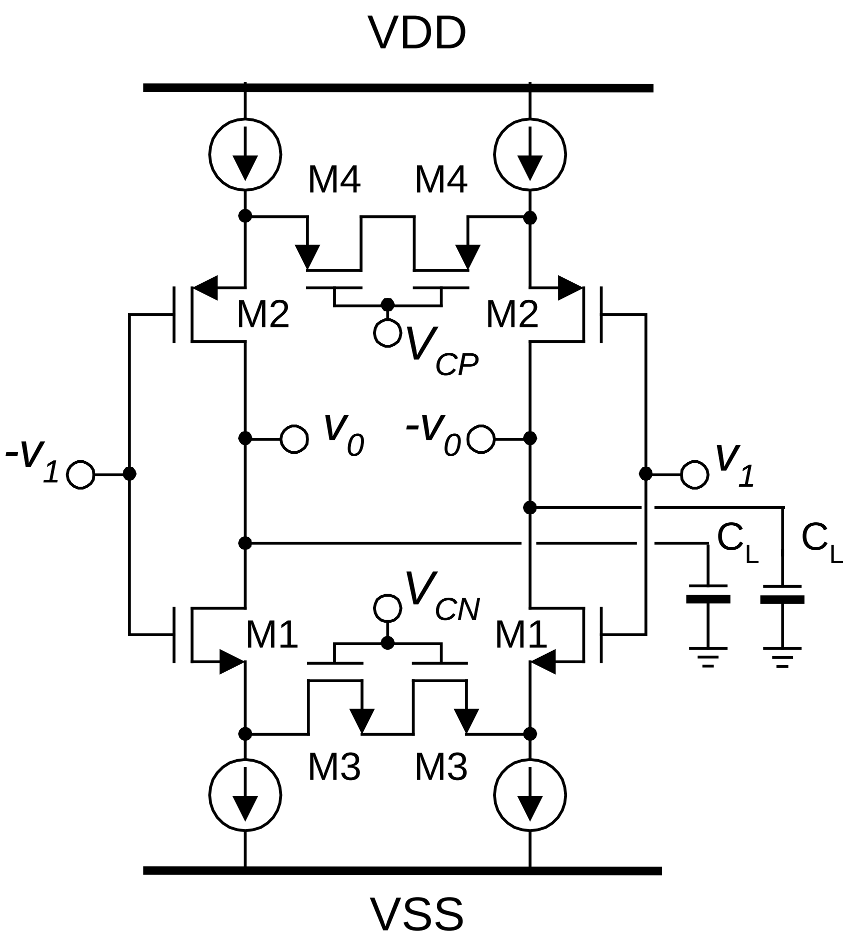


Little sensitive to supply noise and Common-mode noise

Efficient CMFB for Pseudo-Differential OTAs



OTA based on complementary differential pairs



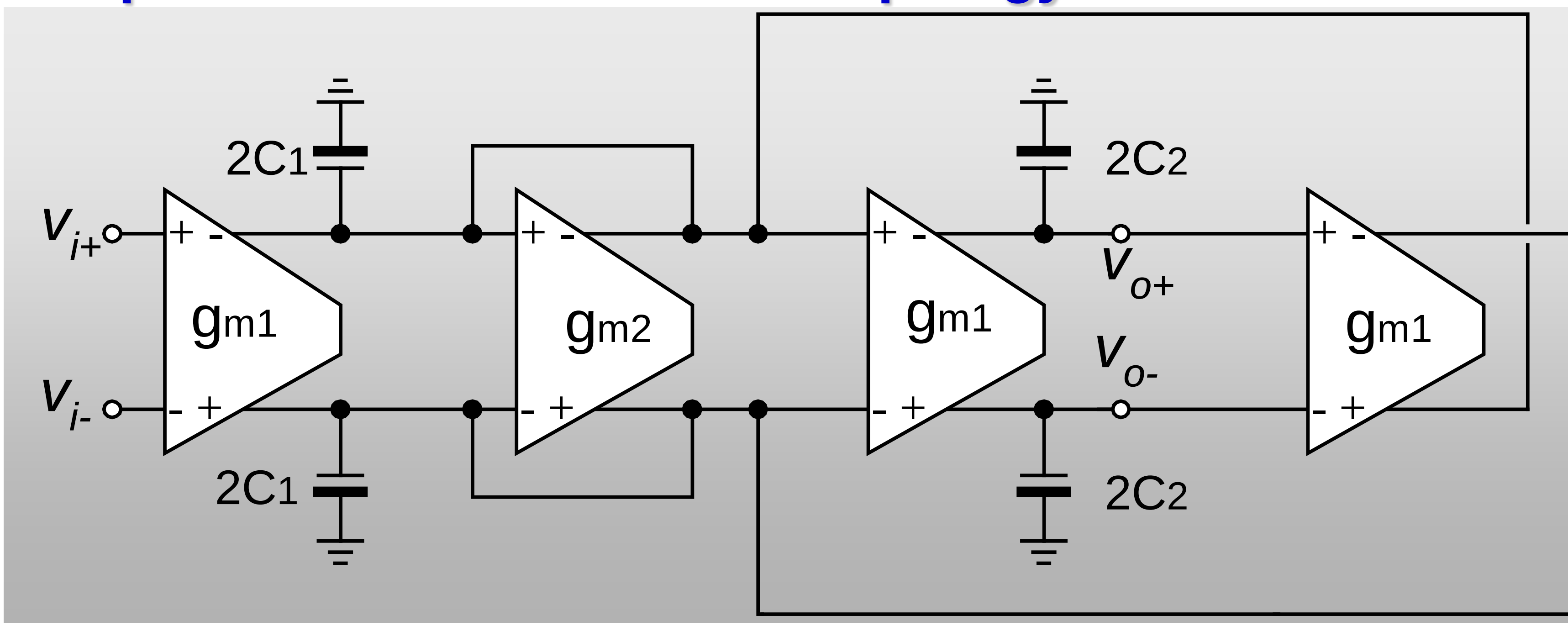
- **Efficient OTA based on linear complementary differential pairs**

$$G_m = \frac{g_{m1}}{g_{m1}R_{M3}+1} + \frac{g_{m2}}{g_{m2}R_{M2}+1}$$

- **Linear circuit due to source degeneration M3 and M4**
- **Suitable for fast applications**

Filter is based on Biquadratic Cells:

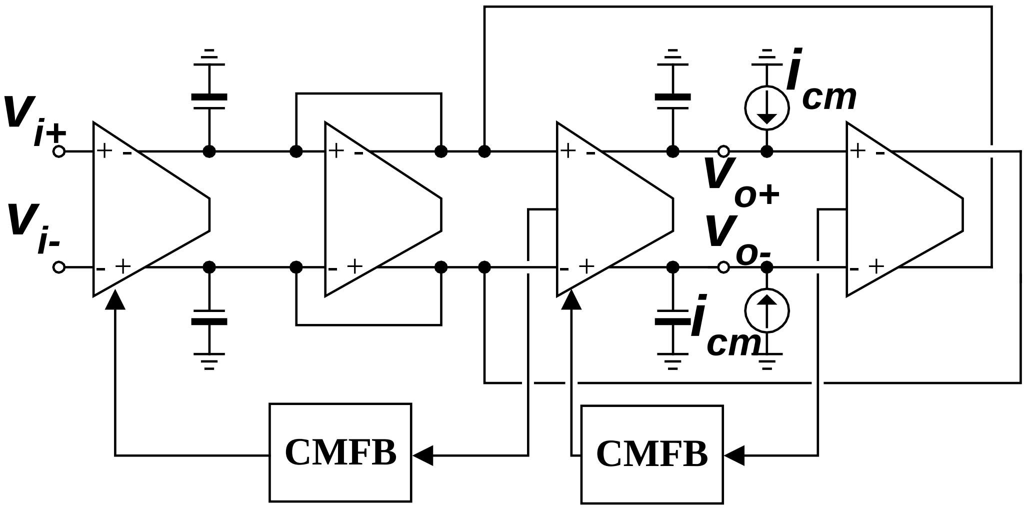
Biquad Realization in Gm-C topology



	f_0 (MHz)	G_{m1} (mA/V)	G_{m2} (mA/V)
Biquad 1	537.6	5.4	9.6
Biquad 2	793.2	5.4	5.07

!!! Fast CMFB is required

Time Domain characterization of the CMFB

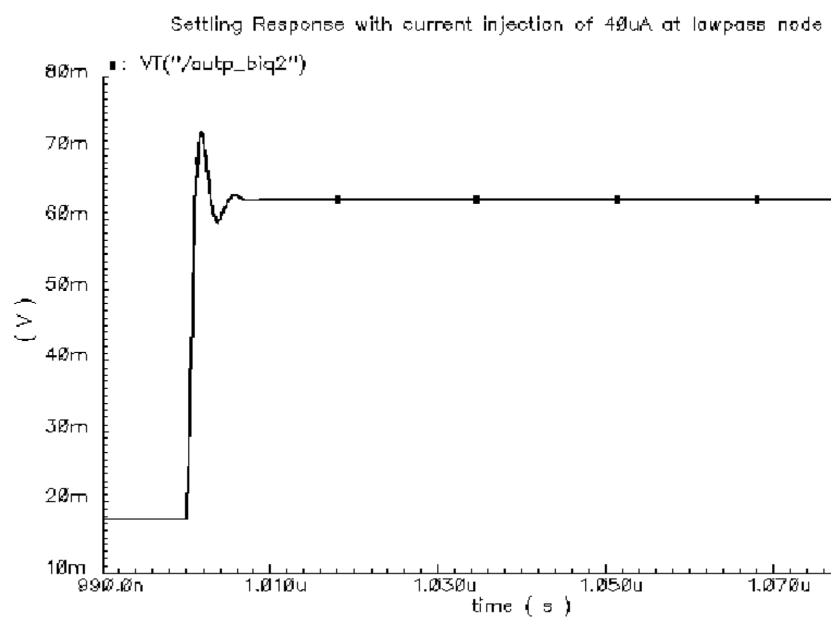


➢Common-mode characterization using common-mode current pulses

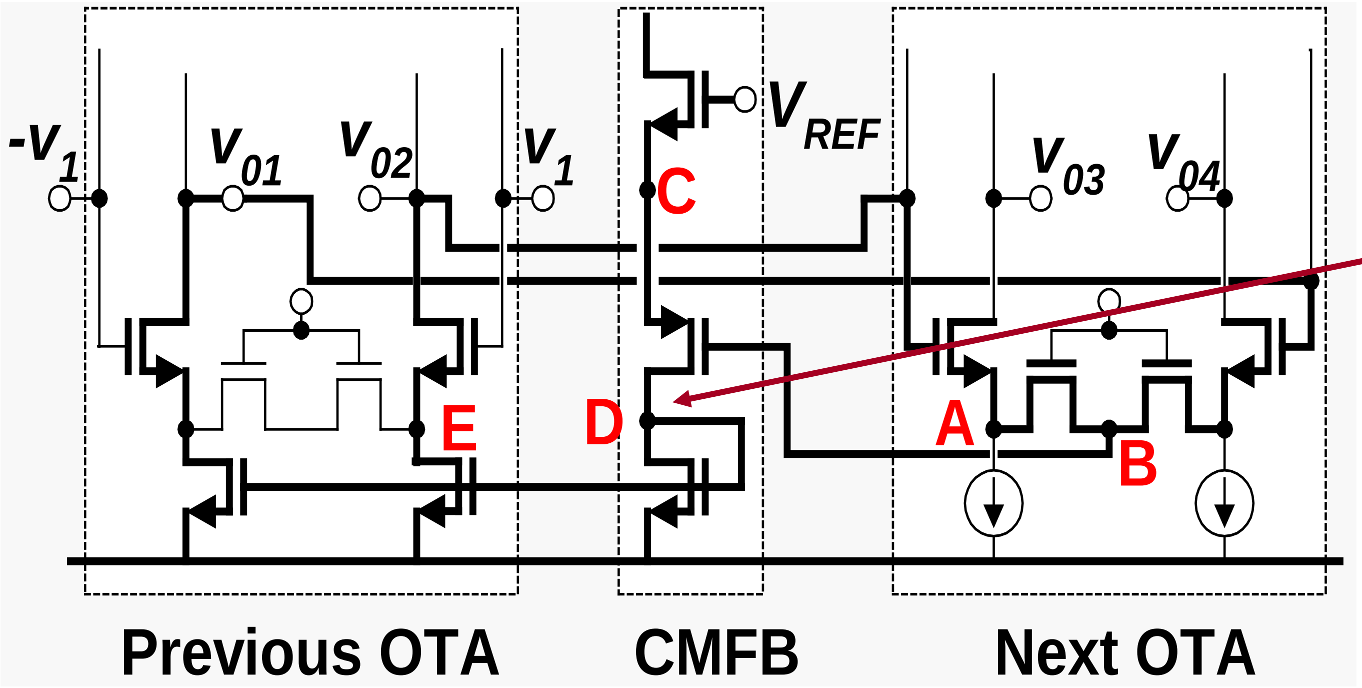
➢One CMFB circuit per pole

•Pulse response of the CMFB

•Phase margin is better than 45 degrees



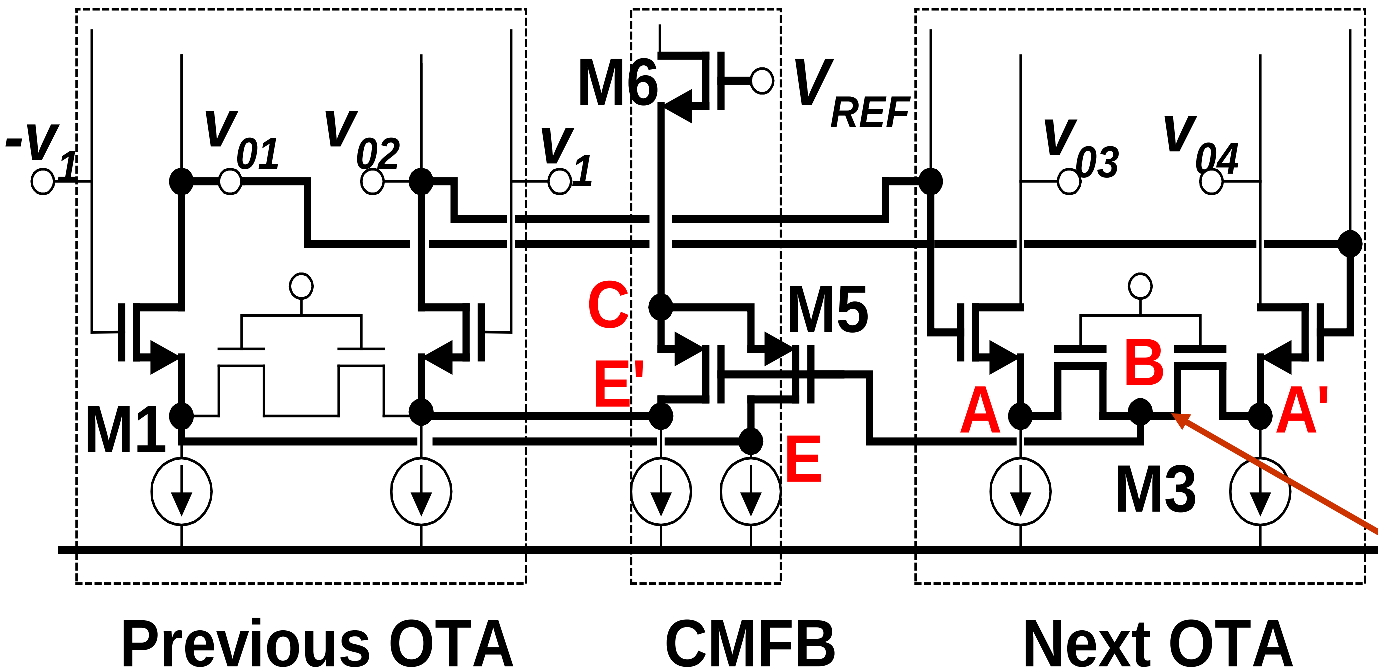
OTA with Class AB Common-mode Feedback



- Most important non-dominant pole at D

- Common-mode signal is detected at next stage
- Class AB error amplifier is used
- 5 non-dominant poles at A~E
- 2 LHP zeros at A and C (Helpful in BW extension)

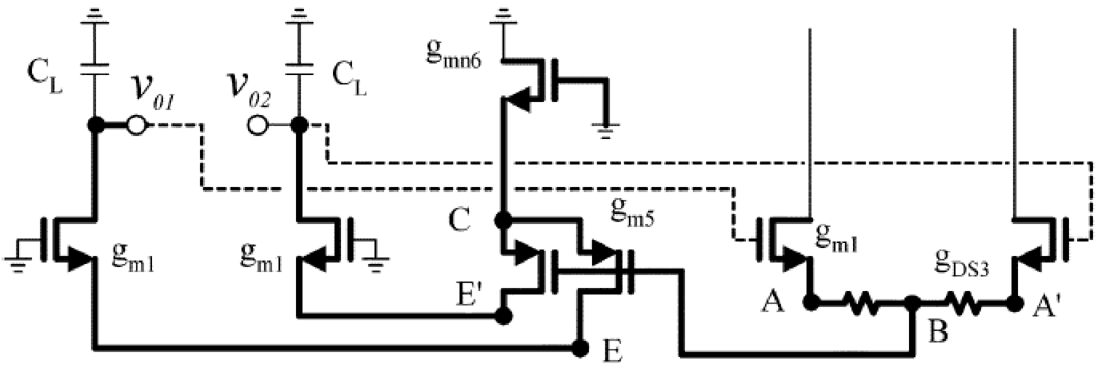
Optimized Class AB Common-mode Feedback



- Most important non-dominant pole at B

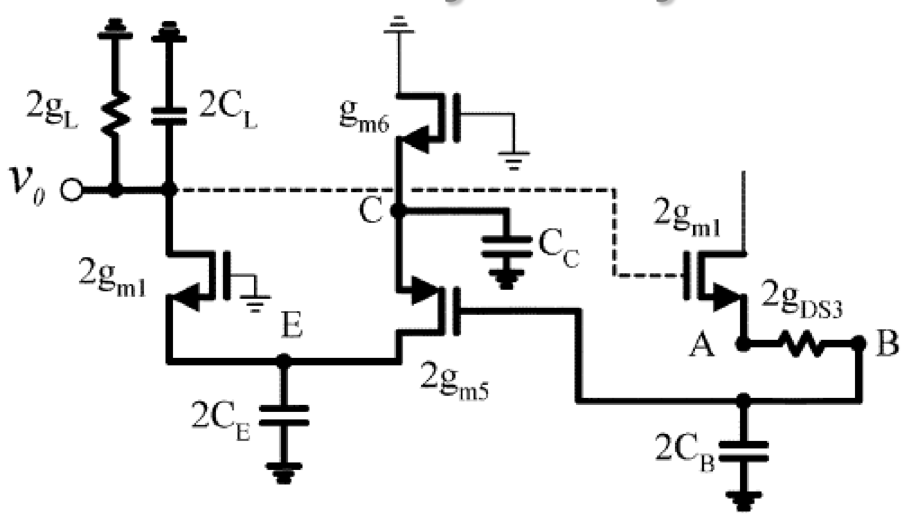
- Class AB error amplifier is used
- 4 non-dominant poles at A~E
- 2 LHP zeros at A and C (Helpful in BW extension)
- Node D was eliminated

Analysis of Class AB Common-mode Feedback



$$A_{VCMFB} \cong \frac{\dfrac{g_{m5}}{\left(1+\dfrac{2g_{m5}}{g_{m6}}\right)g_L}}{\left(1+\dfrac{sC_L}{g_L}\right)\left(1+\dfrac{sC_B}{g_{03}}\right)\left(1+\dfrac{sC_D}{g_{m1}}\right)}$$

CMFB can be simplified taking advantage of circuit's symmetry



- **2 pole-zero pairs (A and C) are very close to each other**

- **More stable CMFB**

Remarks

- DC operating points for high impedances are difficult to fix
- Fully differential amplifiers with high output impedance nodes must use common-mode feedback circuits .
- Common mode circuits can fix the DC operating points as well as minimize the common mode output components.
- Low voltage constraints impose optimal bias conditions at both the input and output ports of an amplifier.
- Common mode circuits for LV should be used both at the input and output

Next Time

- Analog Applications
  - OTA-C Filters
  - Variable-Gain Amplifiers
  - Switch-Cap Filters, Broadband Amplifiers
- Output Stages
- Bandgap Reference Circuits
- Distortion