ECEN474: (Analog) VLSI Circuit Design Fall 2011

Lecture 20: Common-Mode Feedback Circuits

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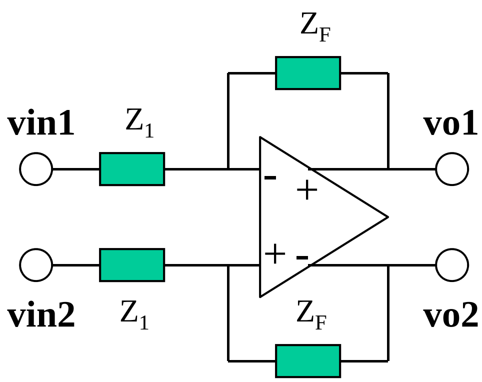
Agenda

- Common-Mode Feedback Circuits

What is a common-mode feed-back correction circuit ?

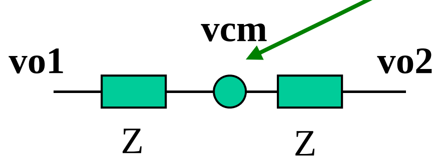
A common mode feed-back circuit is a circuit sensing the common-mode voltage, comparing it with a proper reference, and feeding back the correcting common-mode signal (both nodes of the fully-differential circuit) with the purpose to cancel the output common-mode current component, and to fix the dc outputs to the desired level.

Fully-Differential Filters: CMFB Principle



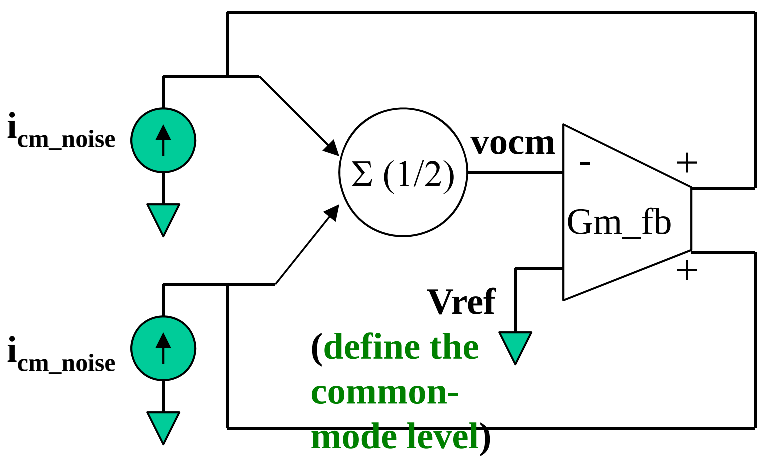
- A common-mode feedback loop must be used: Circuit must operate on the common-mode signals only!
- BASIC IDEA: CMFB is a circuit with very small impedance for the common-mode signals but transparent for the differential signals.
- Use a common-mode detector (eliminates the effect of differential signals and detect common-mode signals)
- Analyze the common-mode feedback loop: Large transconductance gain and enough phase margin
- Minimum power consumption

Simplest common-mode detector



$$v_{cm} = \frac{v_{01} + v_{02}}{2}$$

CMFB Principles: Analysis of the loop for common-mode signals only



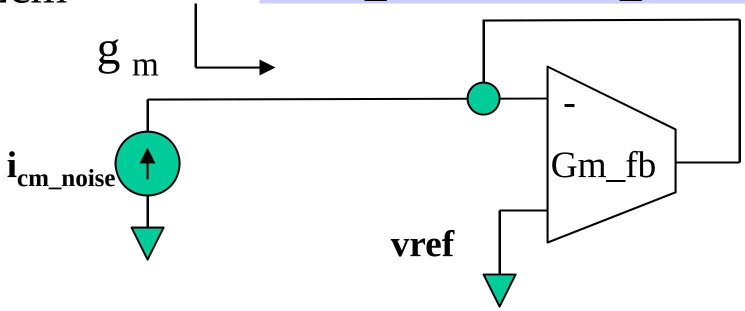
- Analysis for common-mode noise; for instance noise due to power supplies:
- io1=io2=icm_noise

- **The two outputs can be connected together for the analysis of the CMFB loop!**

➔Effect of common-mode noise:

$$Zcm = \frac{1}{g_m}$$

$$v_{cm\_noise} = i_{cm\_noise}/G_{m\text{-}fb}$$



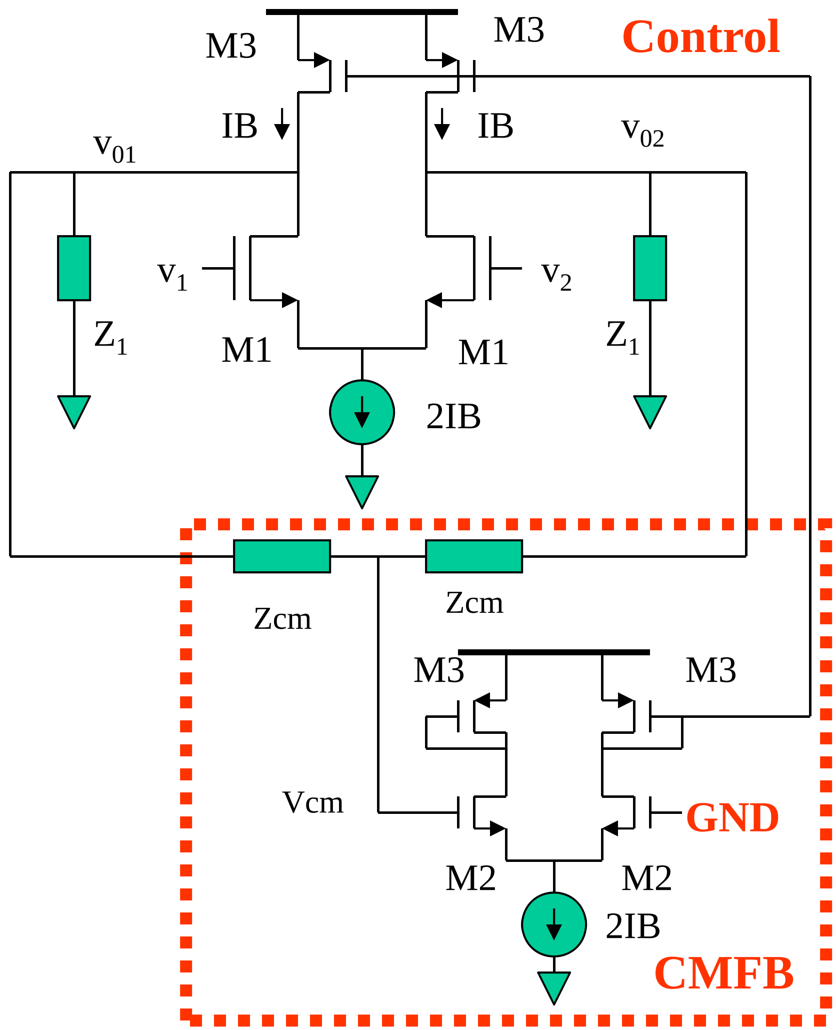
- **BASIC CONCEPTS:**

- The common-mode input noise is converted into a common-mode voltage (common-mode voltage noise) by the common-mode transconductance of the CMFB =1/Gm_fb.

- **common-mode voltage variations $v_{cm\_noise}=i_{cm\_noise}/G_{m\_fb}$!!**

- **The larger Gm_fb the smaller the effects of the common-mode noise!**

Fully-Differential Filters: CMFB



➢**CMFB Characteristics:**

➢Transconductance gain=$g_{m2}/2$ (no PMOS mirror in CMFB OTA)

➢dominant pole at the output

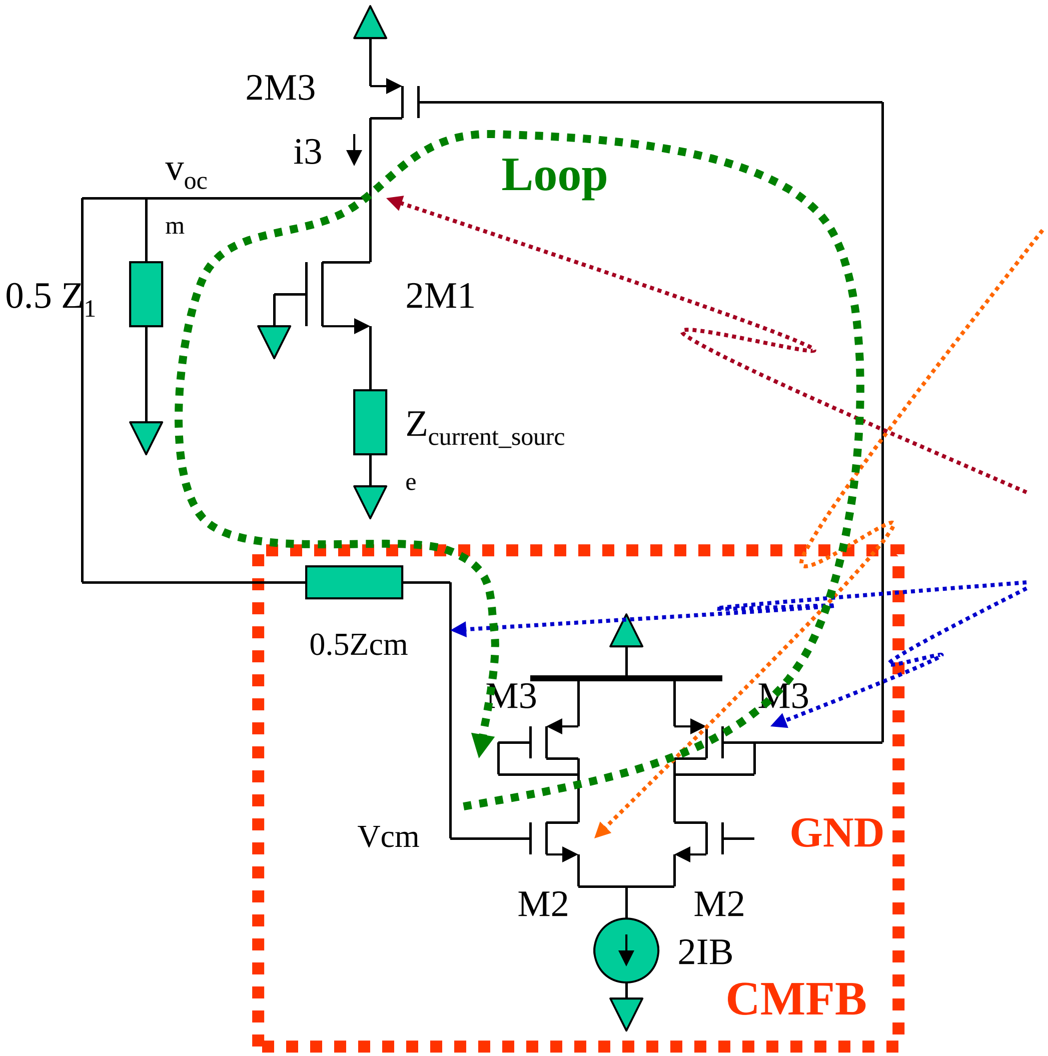
➢At least 2 additional poles in the loop

➢Zcm reduces the OTA dc gain, affecting the differential gain

➢NOTE THAT Vcm IS FORCED TO BE AROUND THE GROUND LEVEL.

➢**DC OFFSET VOLTAGE IS AROUND 2*Ioff/gm2**

Fully-Differential Filters: CMFB



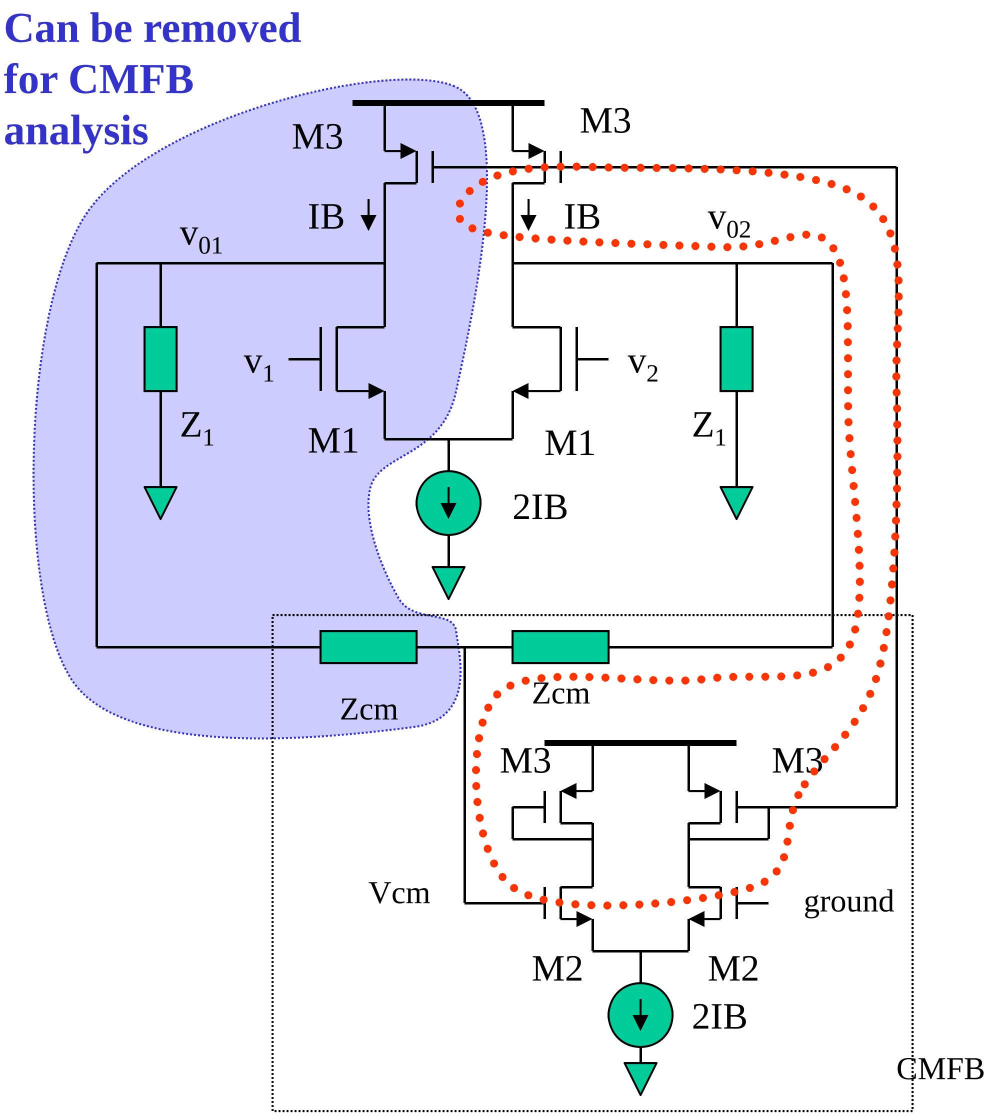
- **CMFB Characteristics:**
- DC Transconductance gain=$g_{m2}/2$
- Loop gain (ignoring poles)

$$\approx\left(\frac{g_{m2}}{2}\right)\left(\frac{1}{g_{m3}}\right)\left(-2g_{m3}\right)\left(\frac{Z_1}{2}\right)=-\frac{g_{m2}Z_1}{2}$$

- dominant pole at the output
- At least 2 additional poles in the loop

- **DC OFFSET IS AROUND 2Ioff/gm2**

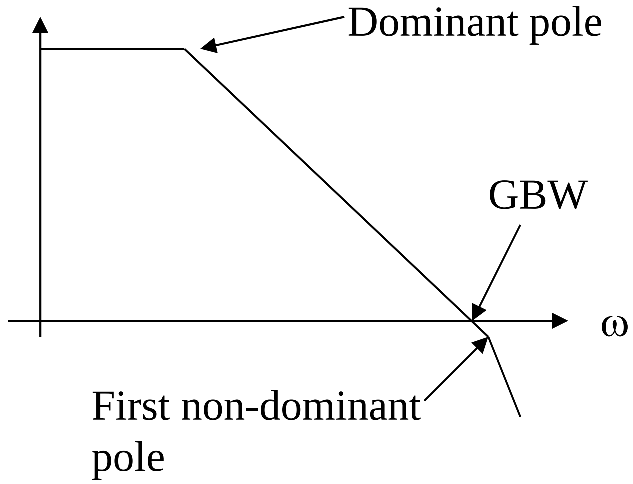
Fully-Differential Filters: CMFB Principles



- **Common-mode stability: DC gain and most relevant poles**

- 1 pole at vcm (1/RC)
- 1 pole at gate of M3 (g_{m3}/C_{P3})
- 1 pole at the output (g_{01}/C_1)

- **dc gain = 0.5 $g_{m2}R_{01}$**



Be sure phase margin > 45º

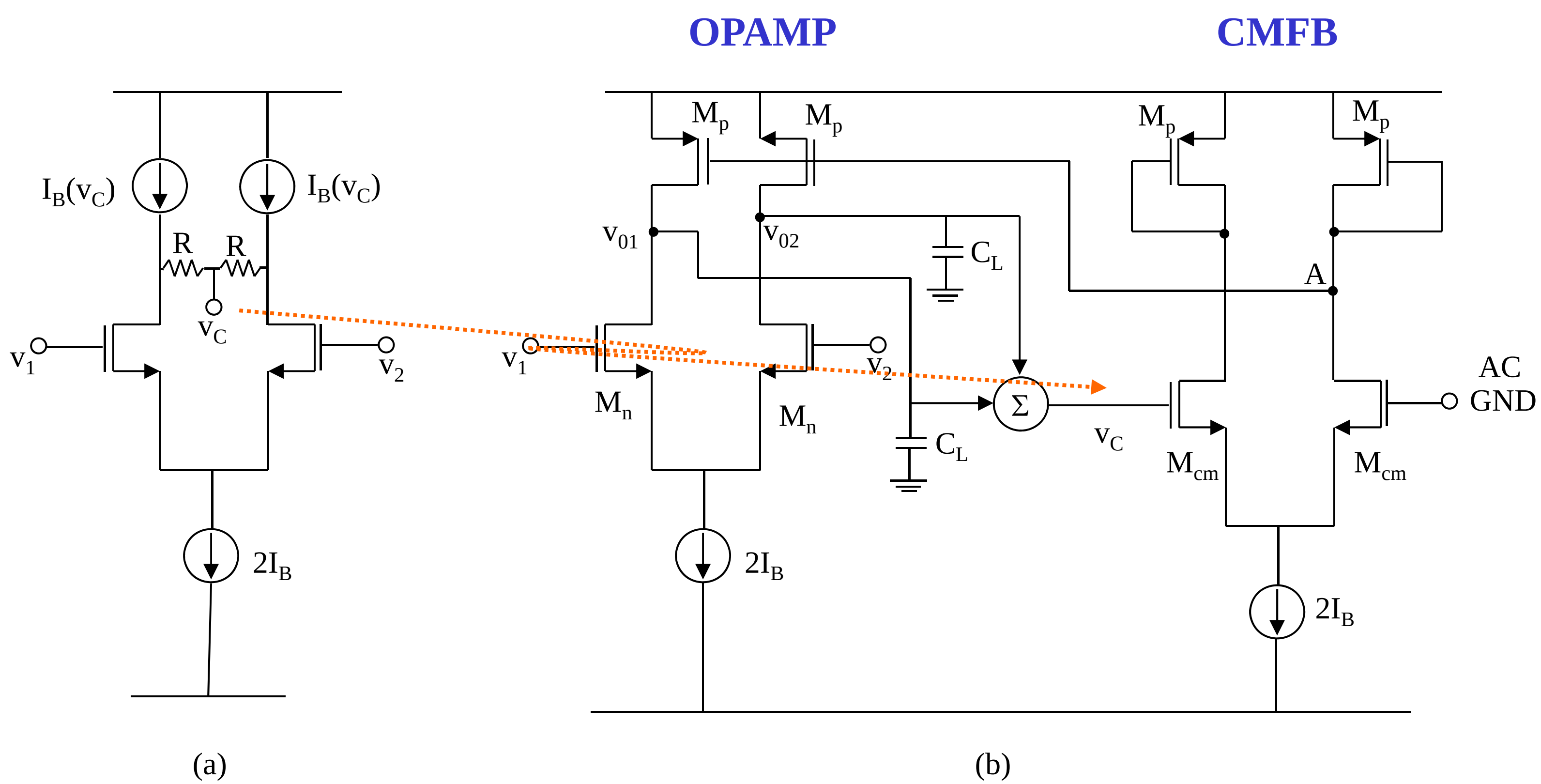
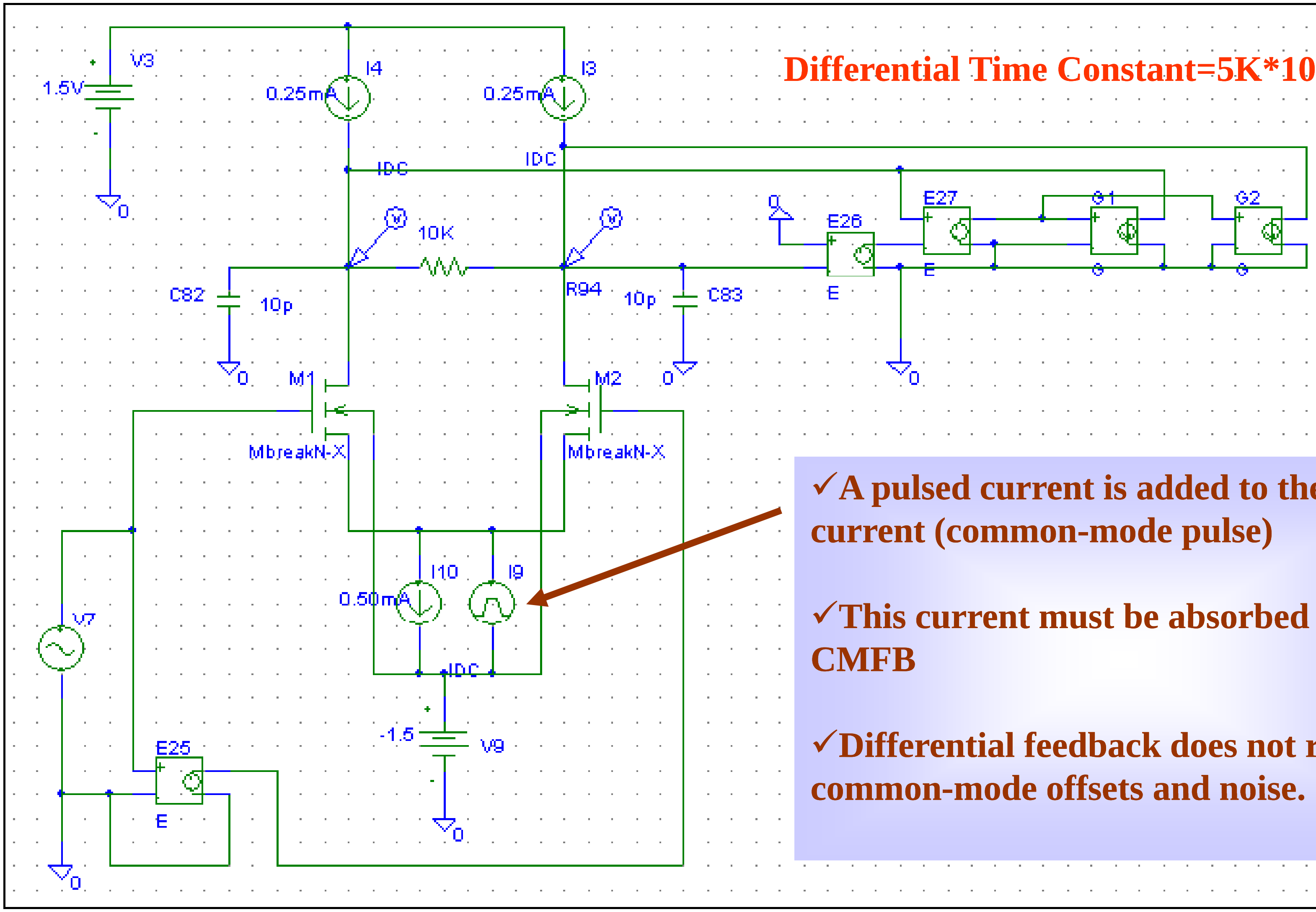


Fig. 3 Common-mode feedback basic circuit concept. (a) Basic common-mode detector, (b) A CMOS CMFB Implementation.

Notice that the resistors R reduce the differential gain!

Fully-Differential Amplifiers: Common-mode pulse



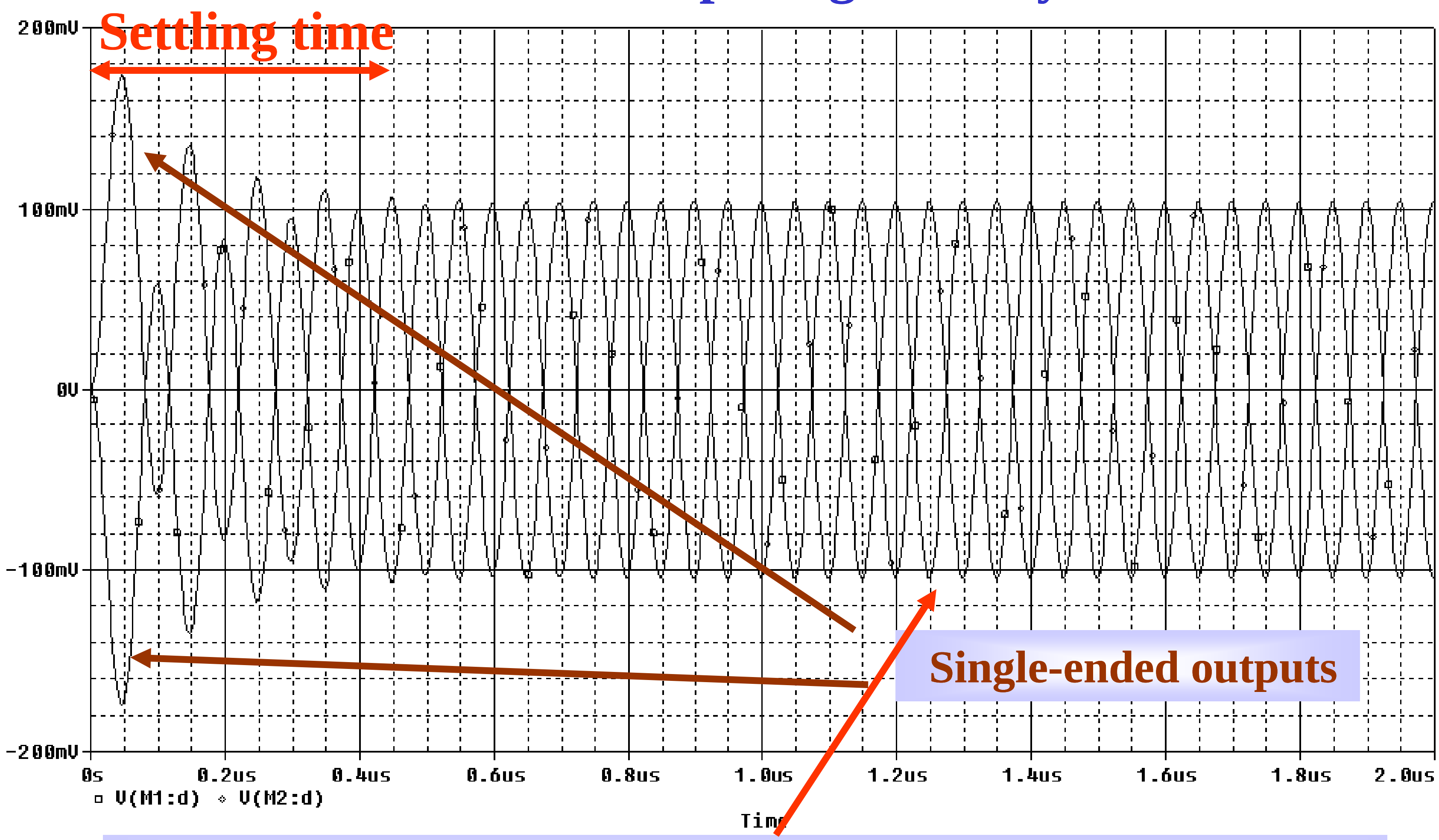
Differential Time Constant=5K*10P=50nsecs

✓A pulsed current is added to the tail current (common-mode pulse)

✓This current must be absorbed by the CMFB

✓Differential feedback does not reduce common-mode offsets and noise.

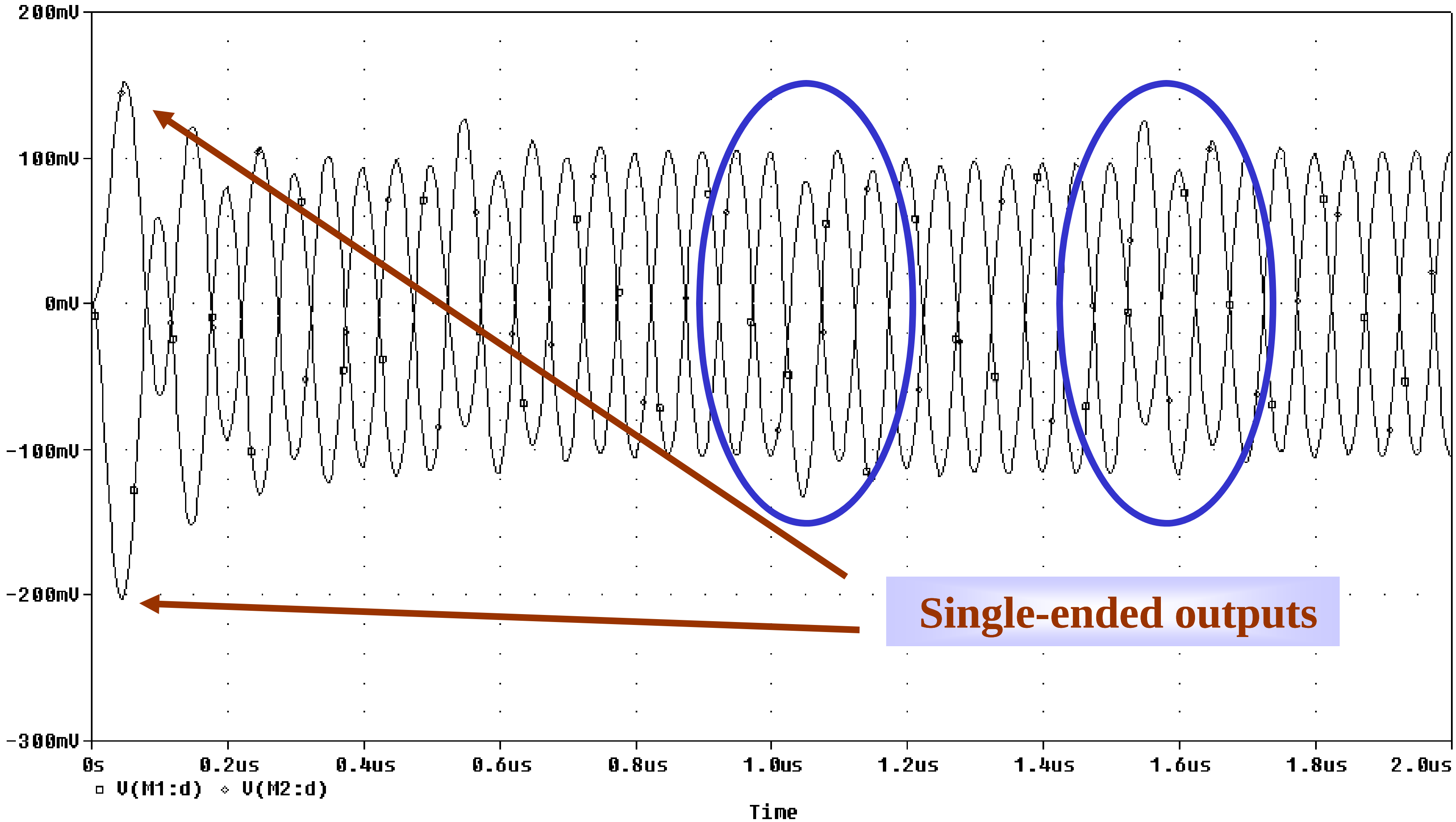
Fully-Differential Amplifiers with CMFB
Differential input signals only



Seems to be that the system is working fine, isn't it?

Fully-Differential Amplifiers with CMFB

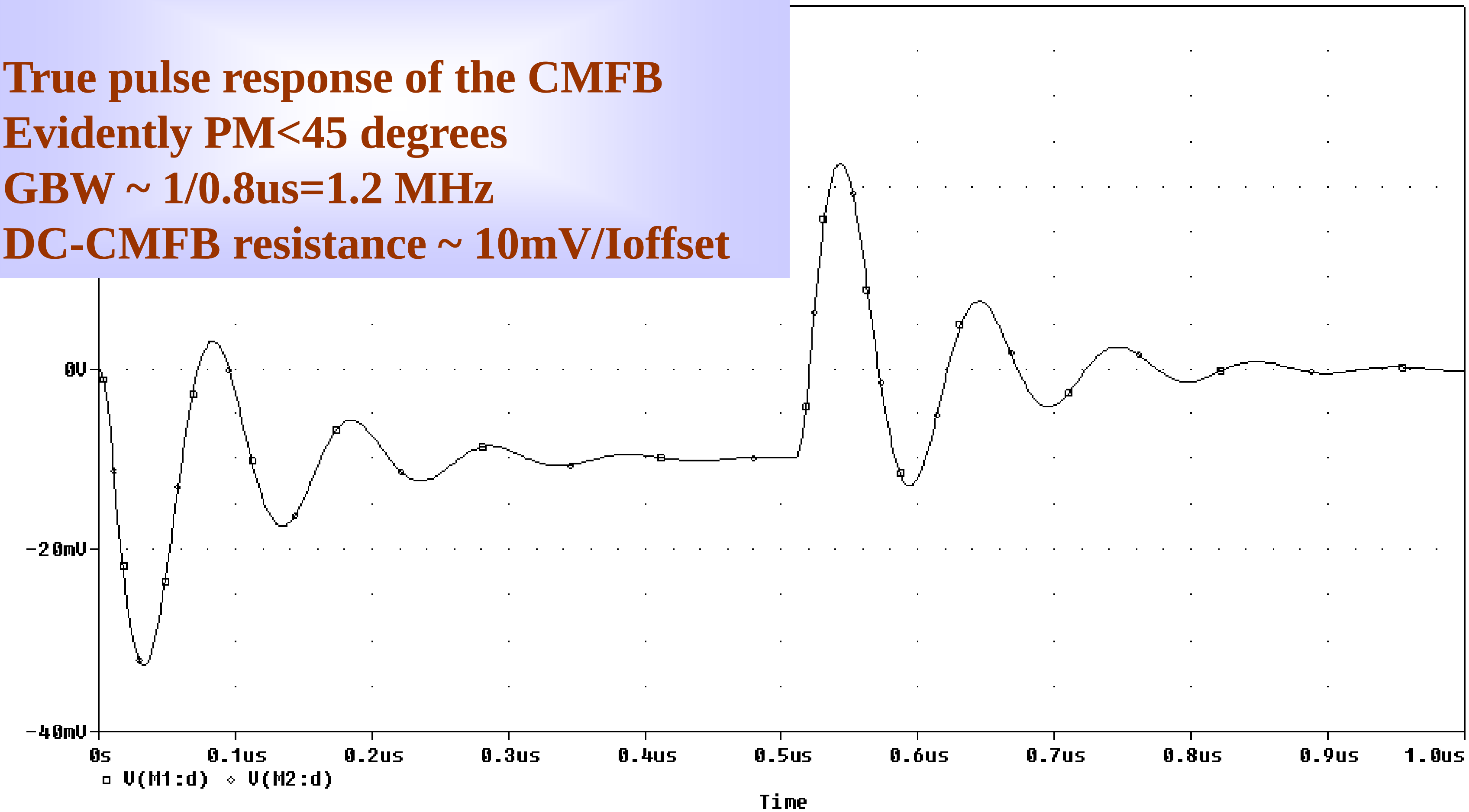
Differential input signals + common-mode pulses



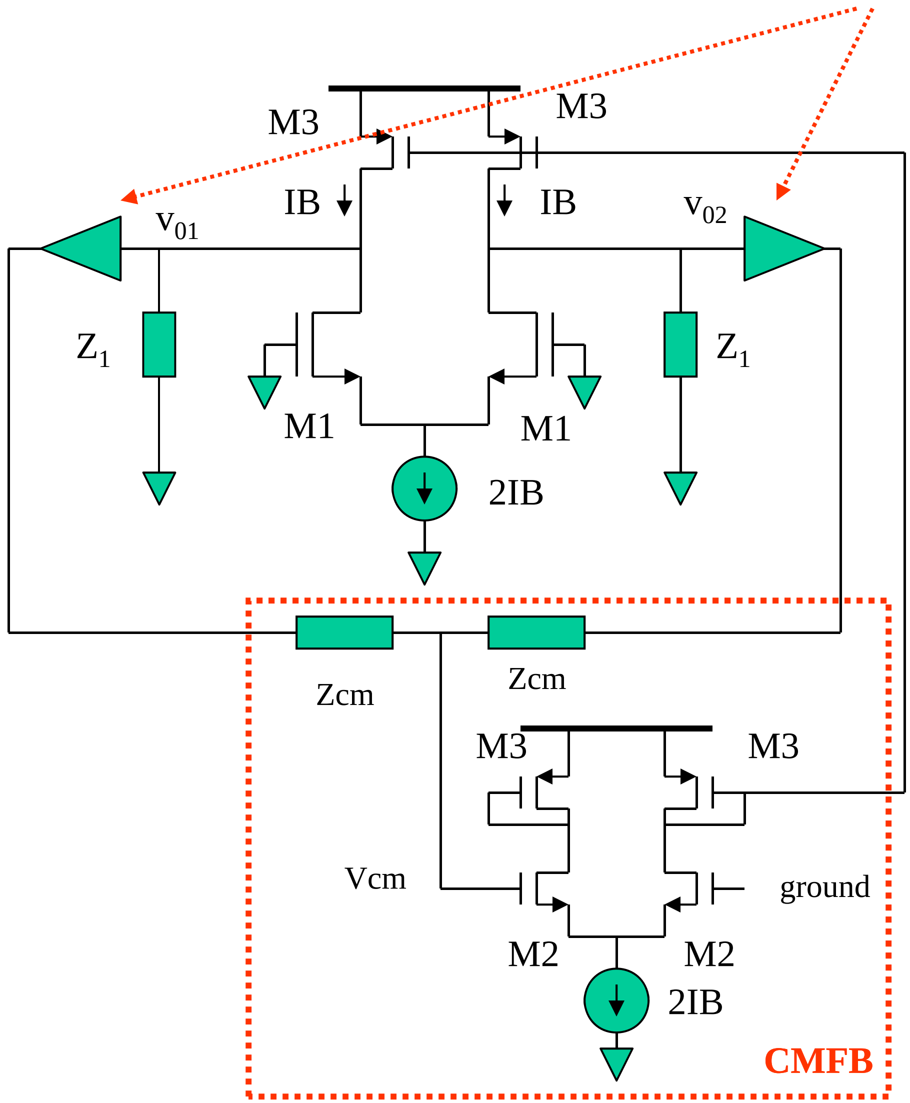
Fully-Differential Amplifiers with CMFB
Differential input signals + common-mode pulses

Common-mode output

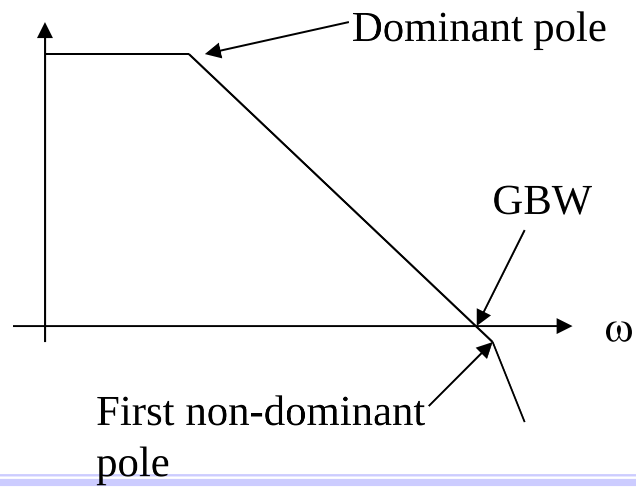
True pulse response of the CMFB
Evidently PM<45 degrees
GBW ~ 1/0.8us=1.2 MHz
DC-CMFB resistance ~ 10mV/Ioffset



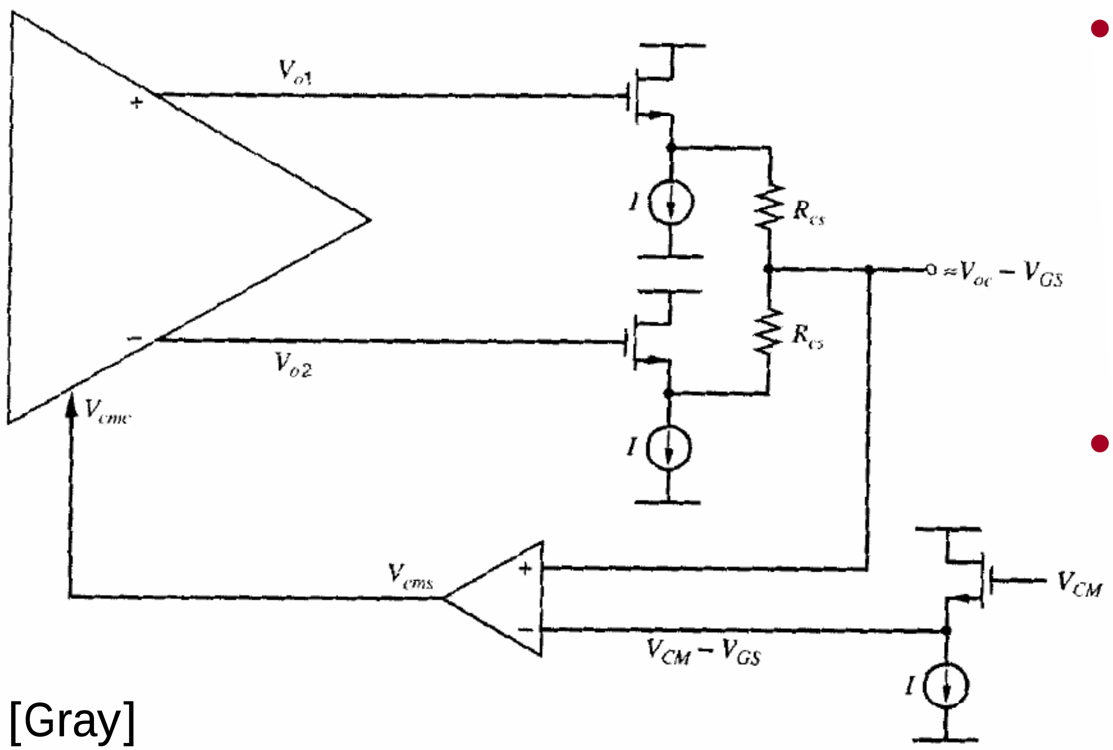
Fully-Differential Filters: Adding buffers to handle the resistive CM-detector



- **The stability conditions are exactly the same for OTA's and OPAMP's:**
- 1 pole at vcm (1/RC)
- 1 pole at gate of M3 (g_{m3}/C_{P3})
- 1 pole at the output (g_{01}/C_1)
- **In OPAMP's you can use resistors as common-mode detector due to the presence of the output buffers**
- dc gain = $0.5 g_{m2} R_{01}$



Isolated Common-Mode Sensing



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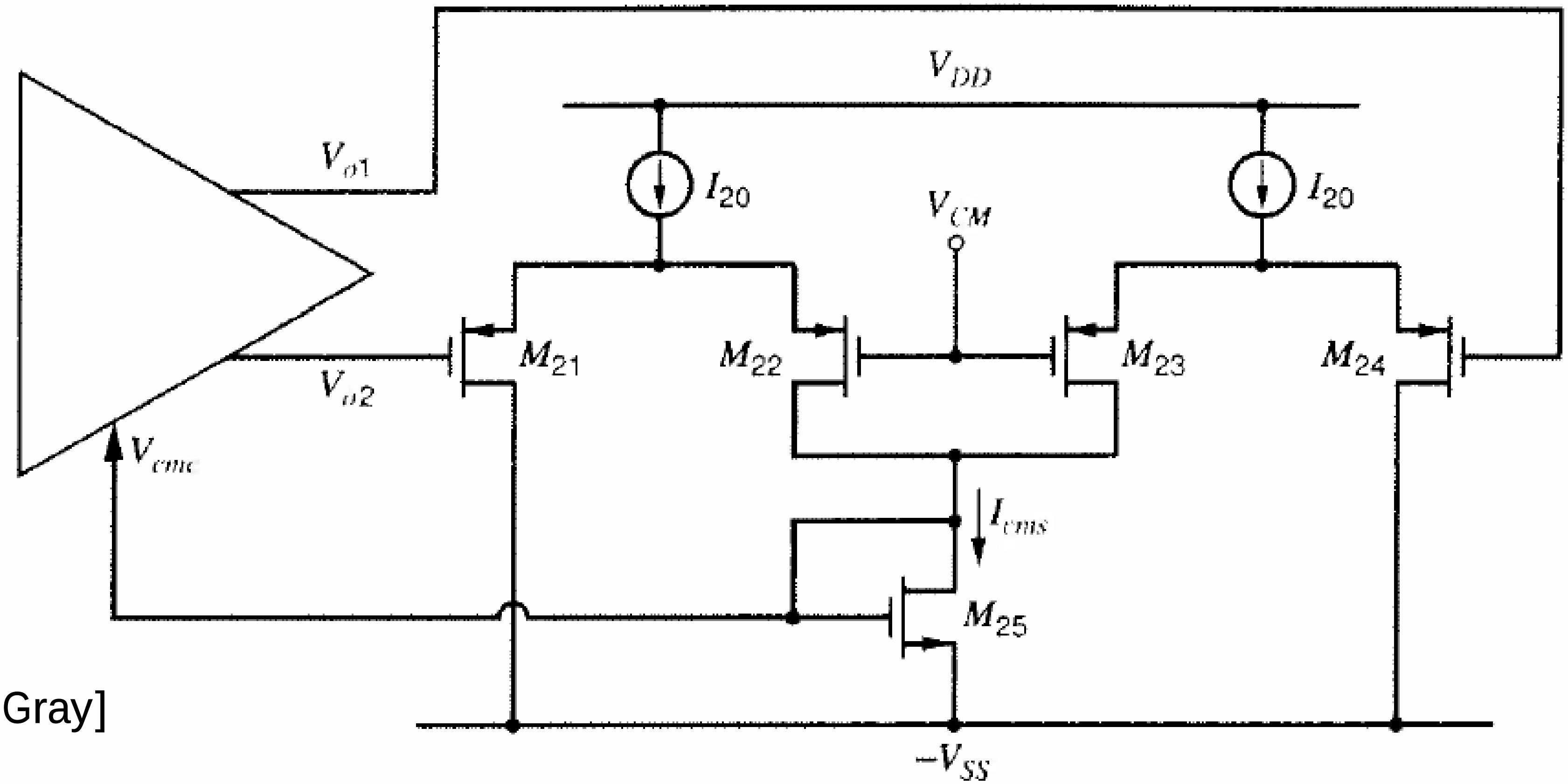
- Source-Followers isolate the loading of the common-mode sensor resistors
- Need to have a replica source follower to set the appropriate reference level for the CMFB amplifier

Two Differential Pair CM Sensor



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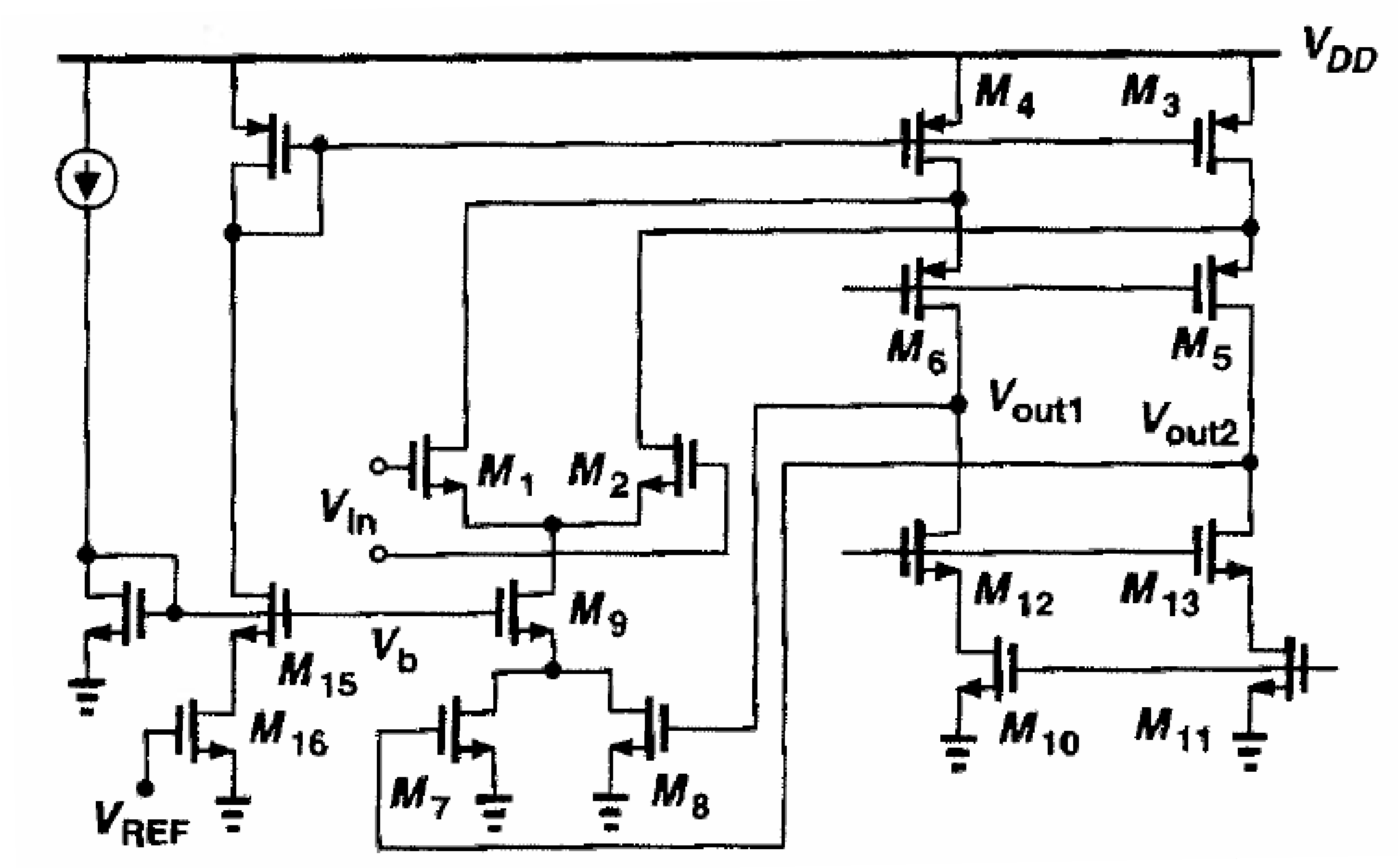
$$I_{cms} = I_{20} + g_{m22}(V_{oc} - V_{CM})$$

$$G_{cmf} = g_{m22}$$

CMFB w/ Triode Devices in Tail Current Source

[Razavi]



Next Time

- Common-Mode Feedback Wrap-Up
- Variable Gain Amplifiers