Linear settling time

$$\tau = \frac{1}{\omega - 3dB} = \frac{1}{\beta \omega_{ta}}$$

Folded cascade OPAMP $\omega_{ta} = \dfrac{g_{m_1}}{C_L}$

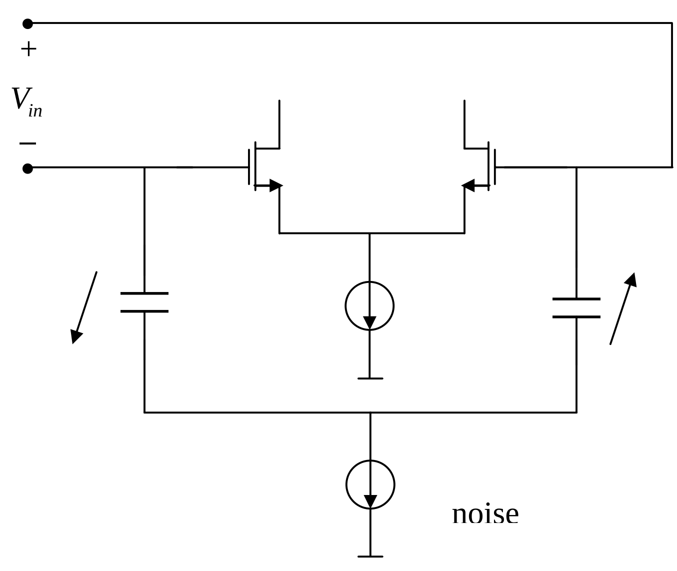
Current Mirror OPAMP $\omega_{ta} = \dfrac{kg_{m_1}}{C_L}$

## <u>Fully differential OPAMPs</u>

differential-in $\rightarrow$ differential-out

Use symmetry to reject substrate noise (unwanted coupling) because transistors are non-linear (junction capacitances vs. voltage)

- $\Rightarrow$ Noise injection depends on voltage levels
- $\Rightarrow$ You cannot reject noise 100%




$\Rightarrow$ Noise injection depends on input signal

Drawback of fully differential circuits:

→ *CMFB (common-mode feedback circuitry is needed)

There is usually feedback on the OPAMP as well as internal CMFB

→ CMFB loop gain is typically not large → Just enough to prevent drifts

CMFB design → Speed must be high in the order of $\omega_{ta}$

→ Continuous-time circuits usually don't work well for large input signal

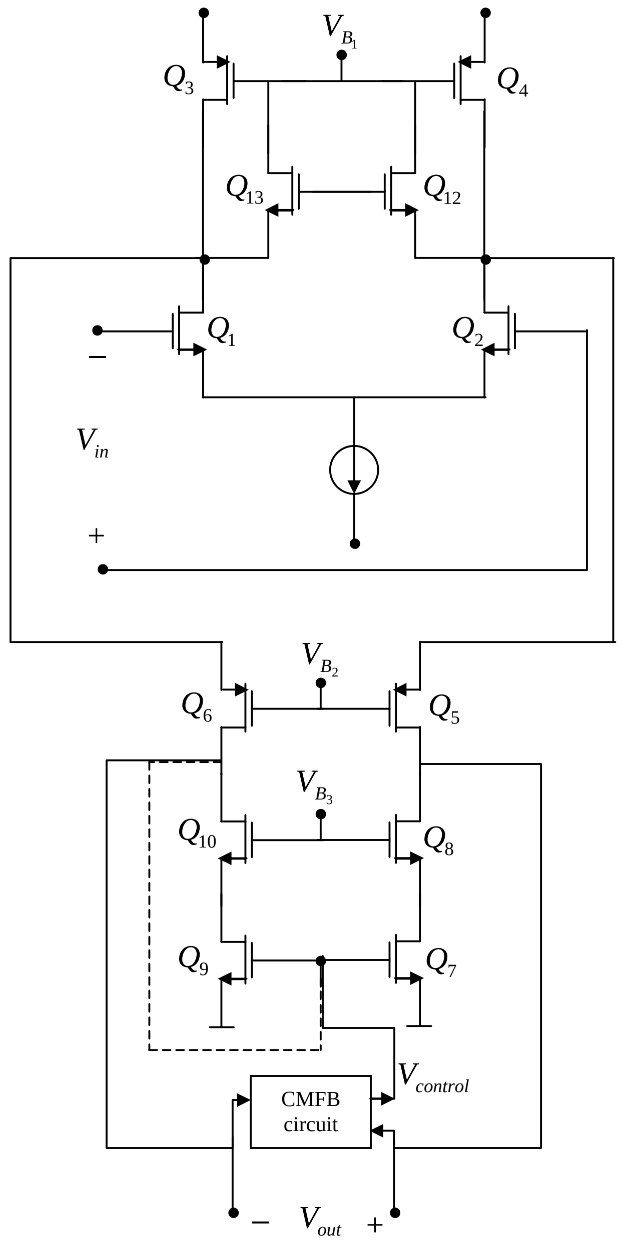
→ Switched-capacitor CMFB's are used:

$\Rightarrow$ Source of noise

$\Rightarrow$ Add to the load capacitance

*Slow-rate usually smaller than single-ended OPAMPS

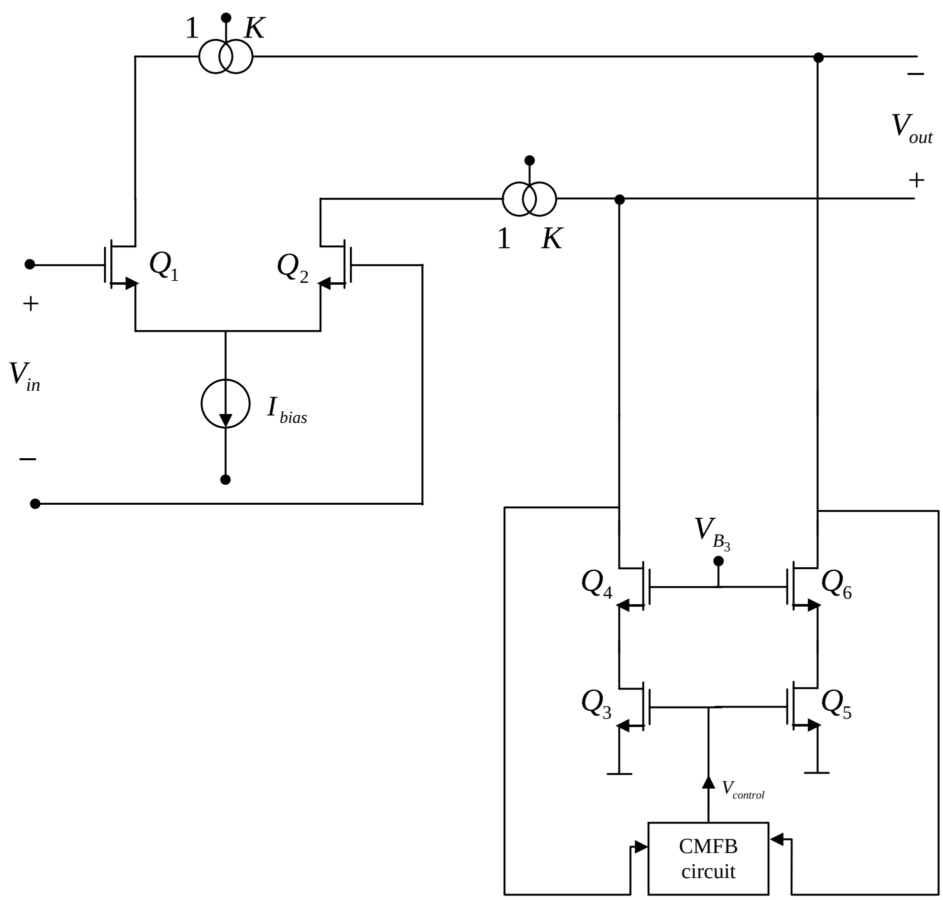
**Fully-additional folded cascade OPAMP**



## **Fully-differential current mirror OPAMP**

n-channel input $\Rightarrow$ Smaller thermal noise

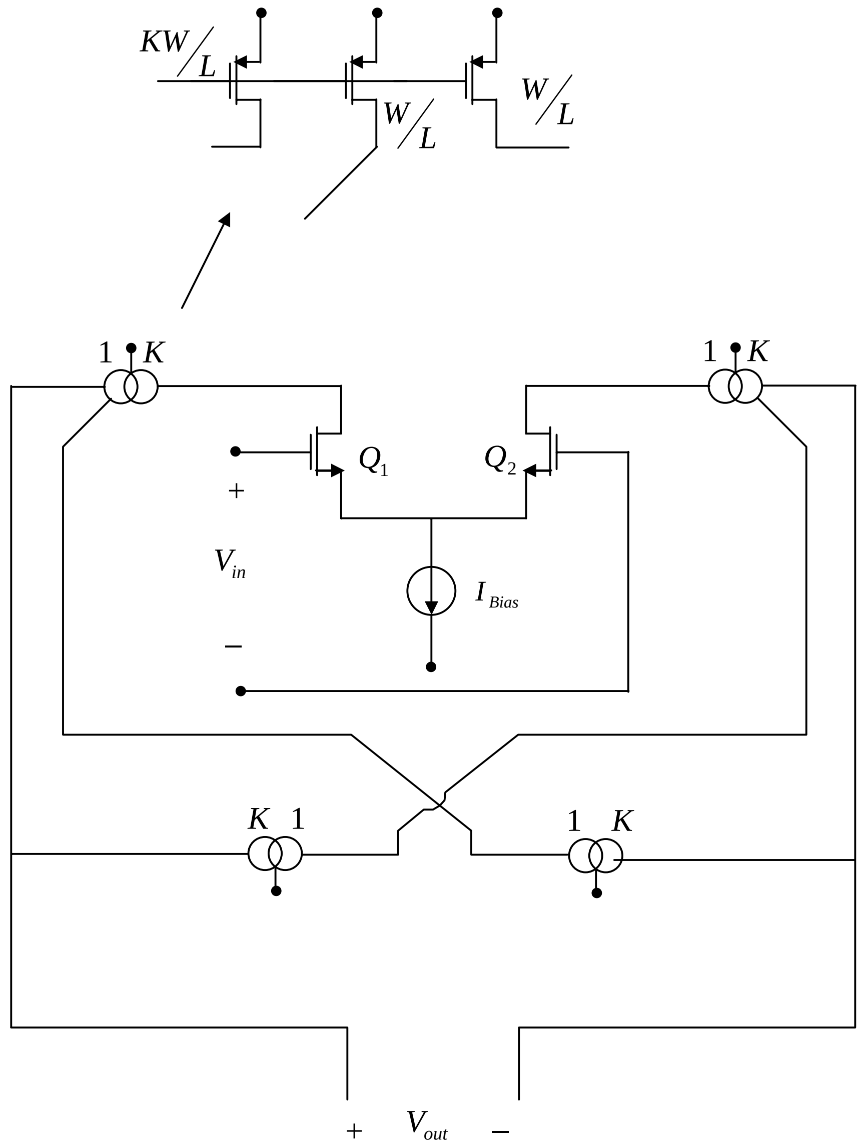
p-channel input $\Rightarrow$ Smaller input $1/f$ noise




To improve the slew-rate one can have bidirectional current (one current charging $C_L$ as the other one is discharging $C_L$'s other plate.

put positive charge on one plate

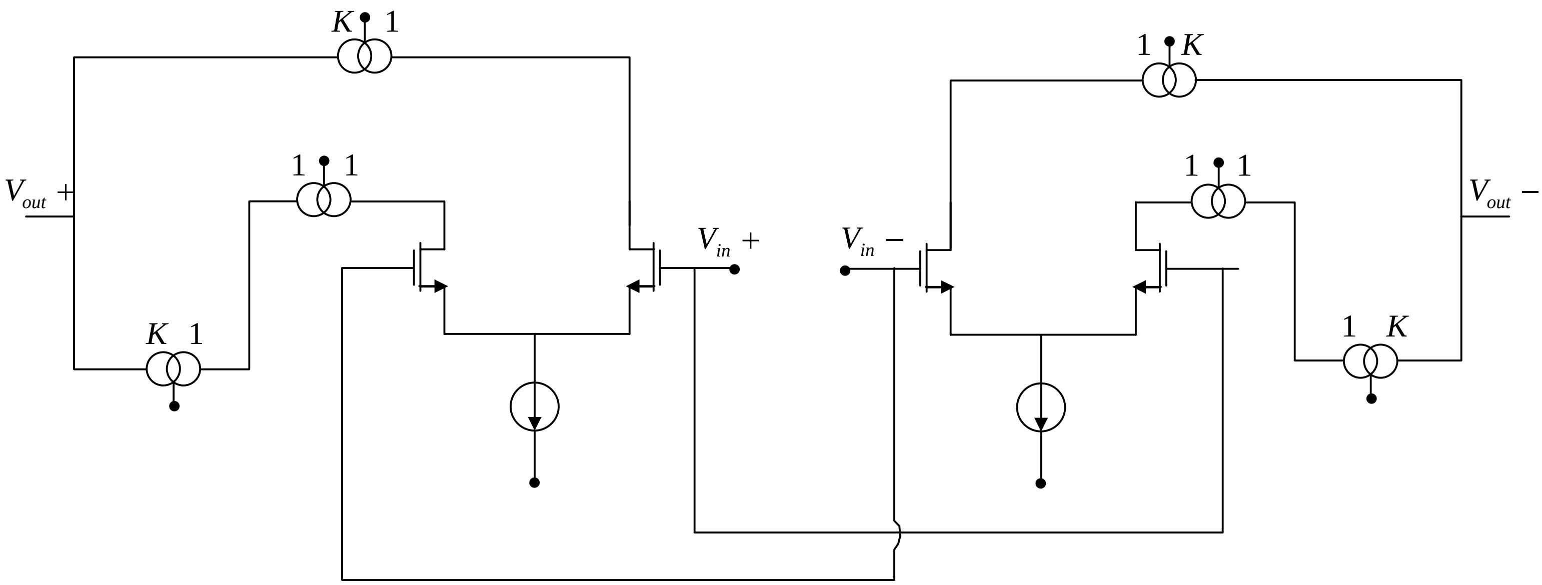
put negative charge on the other plate




* Similar to current mirror fully differential but has bidirectional output drive.

* Improved slew-rate $\frac{2kI_{Bias}}{C_L}$ at the expense of slower small-signal response.

Another fully-diff current mirror OPAMP




If k is large power dissipation is not much higher than other current mirror OPAMPs discussed.

Advantage $\rightarrow$ higher $S/N$ ratio (a factor of $\sqrt{2}$ better)

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* Fig 6-16 and 6-18 are not discussed of the textbook.

* CMFB circuits and current feedback OPAMPs are not discussed.