Offset Cancellation Techniques

\[ V_{os} = \Delta V_{THN} + \frac{1}{2} V_{os} \cdot \frac{\Delta (W/L)}{W/L} \]

To reduce \( V_{os} \),

\[ \text{Area} \sqrt{WL} \]

\[ \Rightarrow \text{Area} \sqrt{WL} \]

\( \Rightarrow \) may degrade speed

\( \Rightarrow \) high power consumption
Need to electronically cancel offset

\[ V_{os} \]

\[ \begin{align*}
V_{os} & \quad C \\
O & \quad + \\
- & \quad - \\
\end{align*} \]

\[ \begin{align*}
A \quad X \\
- & \quad C
\end{align*} \]

when all the voltages are settled, \( AvV_{os} \) is stored on the capacity

\[ \begin{align*}
C & \quad + \quad A_vV_{os}
\end{align*} \]

\[ \begin{align*}
C & \quad - \quad A_vV_{os}
\end{align*} \]
But, for large $|A|$, the circuit can saturate

$|A| \leq 10$

- Need to size the offset at the input side
\[ |Av| \text{ is large} \implies |Av| \gg 1 \]

\[
V_{\text{out}} = V_{xy}
\]

\[
(V_{\text{out}} - V_{os}) (-Av) = V_{out}
\]

\[
\implies V_{\text{out}} = \frac{Av}{1+Av} V_{os}
\]
Input offset storage and cancellation

\[
\frac{AV}{1+AV}V_{os} - V_{os} = V_{os} \left[ \frac{AV}{1+AV} \right]
\]

\[
= -\frac{V_{os}}{HA} = -\frac{V_{os}}{A}
\]

Output referred offset is \( \frac{V_{os}}{A} \) not zero!
Regenerative Comparator

\[ \text{Vin} \rightarrow \text{+} \rightarrow \text{Vout} \]
\[ \text{Vref} \rightarrow \text{-} \rightarrow \text{Vout} \]

\[ \text{If } \text{Vin} > \text{Vref } \Rightarrow \text{Vout=V}_{DD} \]
\[ \text{else }, \text{Vout = 0.} \]

- high input resolution \( \Rightarrow \) \( \pm 1\mu V \Rightarrow \text{high gain} \)
- high speed operation \( \Rightarrow \) \( \text{high speed} \)

\[ \text{Ideal} \]
\[ \text{gain: } A_v \]
\[ \text{BW: } \infty \]

\[ \Rightarrow \text{Cascade several stages to get large gain} \]

\[ n \text{ stages} \]
\[ \text{gain} = A_v^n \]
\[ \frac{A_v^n}{(1+j\omega t_f)^n} \]
Idea 2: Use positive feedback

Let's say we want to compare $V_{in}$ with $V_{out} = 0$.

Input sampled on the capacitor $C$

$V_{in}$ 
\[ \begin{array}{c}
\text{+} \\
\text{C} \\
\text{-}
\end{array} \\ V_C \]  

* Add more charge if $V_{in} > 0$

* Inject current into $C$

* $V_C$ will reach $\infty$

* Conversely, stop current from $C$

$V_C$ will decrease to $-\infty$
$i_c = C \frac{dv_c}{dt} = g \cdot v_c$

$v_c(t) = v_o e^{\frac{t}{\tau}}$

Initial value is $v_o$

@ $t = 0$, $v_c = v_o$

@ $t \to \infty$

$v_c \to \infty$ for $v_o > 0$

$v_c \to -\infty$ for $v_o < 0$

Time constant $\tau = C/G$

Pole in the RHP

$\Rightarrow$ will eventually hit the rails
\[ T_c = \frac{C}{G} \Rightarrow \text{regenerative time constant} \]

*minimum resolvable voltage* \( < \frac{V_{DD}}{e^{T/A/C}} \), \( T \) is the settling time
Differential Signals:

\[ V_{in} + \Delta V \]

\[ V_{in} - \Delta V \]

Compare the two inputs and figure out if the difference is the or-re.

\( \Delta V \) is the initial signal.

Differential transconductor
High gain around the Vsp

differential $g_m$
Initial signal

redraw