ECEN4827/5827 Lecture 18

• No lecture and no office hours on Monday, October 7
• HW6 due via D2L by 10am MT on Friday, October 11
Op-amp in 0.35u NMOS process

- M1: W=50u, L=1u
- M2: W=50u, L=1u
- M3: W=10u, L=2u
- M4: W=10u, L=2u
- M5: W=50u, L=2u
- M6: W=100u, L=2u
- M7: W=250u, L=2u
- M8: W=10u, L=2u
- I1: 1µA
- C1: 1pF
- Vp: 1.65V

.vlib 5827_035.lib
.dc Vin 0 3.3 0.01
.op
.ac dec 200 10 100meg
Next topic: DC voltage and current references

**Purpose: bias and active loads**
Goals: set DC bias operating point independent of
- Component tolerances
- Supply voltages
- Temperature

Sensitivity

\[
S_{p}^{I_{ref}} = \frac{\Delta I_{ref}}{\Delta p} = \frac{p}{I_{ref}} \frac{\partial I_{ref}}{\partial p}
\]

Fractional temperature coefficient

\[
TC_{F} (I_{ref}) = \frac{\Delta I_{ref}}{\Delta T} = \frac{1}{I_{ref}} \frac{\partial I_{ref}}{\partial T} = \frac{1}{T} S_{T}^{I_{ref}}
\]
Supply sensitivity for the basic resistor-based bias current mirror

Assume $\Delta V_S$ of $M_2$: $I_{n+} \approx I_1 \frac{(W/L)_2}{(W/L)_1}$.

$I_1$: $V_{DD} = RI_1 + V_{G}$

neglect $V_{G}$, $V_{DD} \approx RI_1$, $I_1 \approx \frac{V_{DD}}{R}$

\[
S_{\frac{I_{n+}}{V_{DD}}} = \frac{\Delta I_{n+}}{I_{n+}} \frac{V_{DD}}{\Delta V_{DD}} = \frac{V_{DD}}{I_{n+}} \frac{\Delta I_{n+}}{V_{DD}} \frac{V_{DD}}{\Delta V_{DD}}
\]

DC solution:

SS gain: $\frac{I_{n+}}{V_{DD}} = \frac{I_{n+}}{I_1} \frac{R}{V_{DD}} = \frac{(W/L)_2}{(W/L)_1} \frac{1}{R}$

$S_{\frac{V_{DD}}{V_{DD}}} = \frac{V_{DD}}{V_{DD}} \frac{(W/L)_2}{(W/L)_1} \frac{1}{R} = \frac{1}{R}$ not good
$V_t$-based current reference

$$I_{ref} = \frac{V_{oss1}}{R_b} = \frac{V_{tn} \sqrt{\frac{I_1}{K_1}}}{R_b} \approx \frac{V_{tn}}{R_b}$$

$$S_{v_{dd}} = \frac{V_{dd}}{I_{ref}} \cdot \frac{I_{ref}}{V_{dd}}$$

$$\frac{I_{ref}}{I_1} = \frac{V_{oss1}}{V_{dd}} \cdot \frac{R_b}{R_1}$$

$$I_1 = g_{m1} \cdot V_{gss1} = g_{m1} \cdot R_b \cdot I_{ref}$$

$$V_{gss1} = R_b \cdot I_{ref}$$

$$\frac{I_{ref}}{I_1} = \frac{1}{g_{m1} R_b}$$

$$S_{v_{dd}} = \frac{V_{dd}}{V_{tn} / R_b} \cdot \frac{1}{g_{m1} \beta} \cdot \frac{1}{R_1} = \frac{V_{dd}}{V_{tn}} \cdot \frac{1}{g_{m1} \beta} \cdot \frac{1}{R_1} \approx \frac{1}{10}$$

$V_{gds1} < 0 \Rightarrow M_1 \text{ AS}$

$\approx \frac{1}{R_1}$

ECEN4827/5827 Analog IC Design
$V_t$-based current reference

Self-biased.

no large resistors required!

$+V_{DD}$

$V_{tn}$

$I_2 \approx \frac{V_{tn}}{R_b}$

$R_b$ is relatively small.