3) Standard opamp topology

Bias network

\[ V_{DSAT5} = V_{OV5} = 100 \text{mV} \Rightarrow V_{OV3} = V_{OV6} = 100 \text{mV} \]

\[ I_f = 100 \mu A \]

\[ 100 \mu A = \frac{M_n \cdot (W/L) \cdot (V_{OV5})^2}{2} \]

\[ \frac{W}{L} = 100 \Rightarrow W_5 = 50 \text{mm} \]

Similarly \( I_D3 = 20 \mu A \Rightarrow W_3 = \text{choose} \ 10 \text{mm} \)

Choose \( I_D6 = 10 \mu A \Rightarrow W_6 = \text{choose} \ 5 \text{mm} \)

Alternatives: could pick \( L \) for all devices to be something larger

- could choose \( I_D6 \) to be something different (but keep it smallish to avoid wasting power)

\[ V_{DD} = 2 \text{V} \]

\[ V_{DD} - I_D6 \cdot R = V_{th} + V_{OV6} = 0.6 \]

\[ R = \frac{1.4 \text{V}}{10 \mu A} = 140 \text{K}\Omega \]
1st stage

pick \( L_1 = L_2 = 0.5 \text{ mm} \)

pick \( V_{ov1} = |V_{ov2}| = 100 \text{ mV} \)

\[
I_{d1a} = \frac{1}{2} I_{d1} = 10 \text{ mA} \Rightarrow \left( \frac{W}{L} \right)_{1A} = \left( \frac{W}{L} \right)_{1B} = 10 \text{ mm} \times 8 \text{ mm} = 10 \text{ mm^2}
\]

\[
\Rightarrow W_{1A} = W_{1B} = 5 \text{ mm}
\]

\[
I_{d2A} = 10 \text{ mA} \Rightarrow 10 \text{ mA} = \frac{M_{text} \times \left( \frac{W}{L} \right)_{2A} (V_{ov2A})^2}{V^2 (\frac{W}{L})_{2A} (0.1 \text{ V})^2}
\]

\[
\left( \frac{W}{L} \right)_{2A} = 20 \Rightarrow W_{2A} = W_{2B} = 10 \text{ mm}
\]

2nd stage

If \( L_2 = 0.5 \text{ mm} \) then \( L_4 \) should be \( 0.5 \text{ mm} \)

\[
I_{d5} = 100 \text{ mA} \Rightarrow I_{d6} = 100 \text{ mA} \Rightarrow \left( \frac{W}{L} \right)_4 = 200, W_4 = 100 \text{ mm}
\]

Spec \( |V_{ov4}| = 100 \text{ mV} \)
b) see typed solutions

\[ V_{\text{out}} = V_{\text{in}} - V_{\text{in}} \cdot V_{\text{th}} \]

\[ V_{\text{th}} = V_{\text{fpm}} + V_{\text{v}} = 0.1V \]

\[ V_{\text{out}} = V_{\text{icm}} - V_{\text{th}} \]

\[ V_{\text{icm}} \]

\[ V_{\text{th}} \cdot V_{\text{in}} + V_{\text{v}} = 0.7 \]

From above, input common node ranges from 0.5 to 1.5 V.

That change of 1.2 V causes a change in tail current of

\[ \Delta V_{V_{\text{in}}} = \frac{1}{5} \cdot 1.2V = 0.24V \]

To improve that we could make L3 longer (and L5 & L6 too).

c) 1\text{st} stage gain \[ A_{V1,0} = -g_{m1}\left(\frac{r_{D1B}}{r_{D2B}}\right) = 0.1\text{ms} (500k\|50k) = -50 \]

2\text{nd} stage \[ A_{V2,0} = -s_{A4}\left(\frac{r_{O4}}{r_{O5}}\right) = -2\text{ms} (50k\|50k) = -50 \]

Overall gain \[ A_{V1,0} \cdot A_{V2,0} = 2500 \]

e) -1 or \(-\frac{1}{4}\) or anything in that range is fine, see typed solutions for more detail.

\[ \omega_p = \frac{1}{(r_{O4}\|r_{O5})C_L} = \frac{1}{(50k\|50k)(0.1\text{pF})} = \frac{1}{2.5\text{ns}} = 400M\text{rad/s} \]

g) \[ C_{gs4} + (1 - A_{V2,0}) C_{sd4} = (2.5\text{pF}) + (51)(50\text{pF}) = 2.8\text{pF} \]

h) \[ \omega_0 = \frac{1}{(r_{O1B}\|r_{O2B})(2.8\text{pF})} = \frac{1}{(250k)(2.8\text{pF})} = \frac{1}{0.7\mu\text{s}} = 1.4M\text{rad/s} \]

i) above 2\text{nd} stage unity gain \[ C_{in} = C_{gs4} + C_{sd4} = 0.3\text{pF} \]