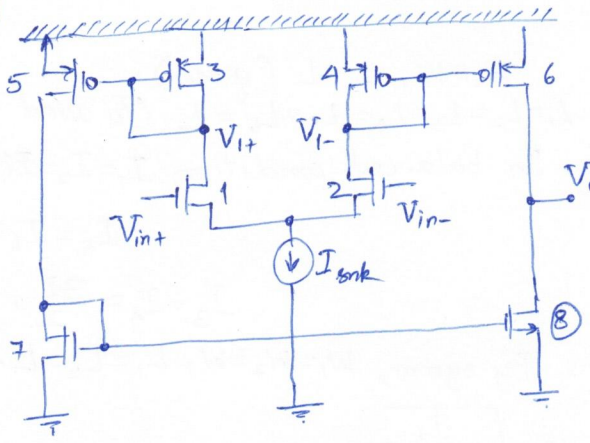
(1)



$$\left(\frac{v_{1+}-v_{1-}}{v_{in+}-v_{in-}}\right)\left(\frac{V_{1+}+V_{1-}}{V_{in+}-V_{in-}}\right) = -\frac{g_{mn}}{g_{mp}+\frac{1}{r_{op}}+\frac{1}{r_{on}}}$$

$$\frac{V_{out}}{v_{1+}-v_{1-}} \approx \frac{g_{mp}}{\frac{1}{r_{on}}+\frac{1}{r_{op}}}.$$

$$\Rightarrow \frac{v_{out}}{v_{in+}-v_{in-}} = -\frac{g_{mn}\,g_{mp}}{\left(g_{mp}+\frac{1}{r_{on}}+\frac{1}{r_{op}}\right)\left(\frac{1}{r_{on}}+\frac{1}{r_{op}}\right)}$$

$$\approx -\frac{g_{mn}}{\frac{1}{r_{on}}+\frac{1}{r_{op}}} = -3m\mho\,(40k\Omega \| 60k\Omega)$$

$$= -3m\mho\left(\frac{2400\,k\Omega}{100}\right) = \boxed{-72}.$$

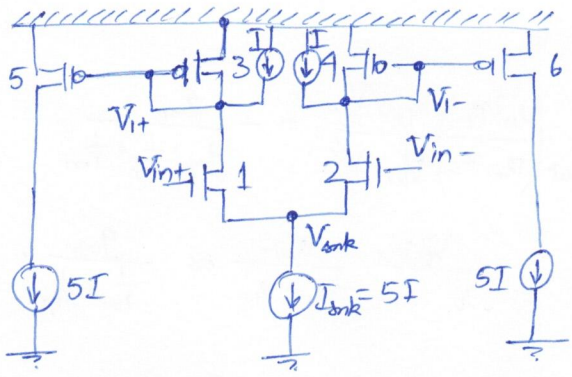
(2) In the balanced state, $I_1 = I_2 = I_3 = I_4 = \frac{I_{sink}}{2}$, and $I_5 = I_6 = I_7 = I_8$.

$V_{out} > V_{GS7} \Rightarrow I_8 > I_7 = I_5 = I_6$ ✗

$V_{out} < V_{GS7} \Rightarrow I_8 < I_7 = I_5 < I_6$ ✗.

Hence, $V_{out} = V_{GS7} = \boxed{V_{bn} + V_{GSTn}}$.

(3)



$W_2 = W$, $L_2 = L$ (given).
$L_1 = L_2 = L_3 = L_4 = L_5 = L_6 = L$ (to avoid length effects).
In balanced condition, $I_1 = I_2 = \frac{5I}{2}$,

$I_5 = I_6 = 5I$,

$I_3 = I_4 = \frac{3I}{2}$.

By symm., $W_1 = W_2 = W$, $L_1 = L_2 = L$.

$$|V_{GST3}| = |V_{GST1}| \Rightarrow \sqrt{\frac{I_3}{\mu_p (W_3/L_3)}} = \sqrt{\frac{I_1}{\mu_n (W_1/L_1)}}$$

$$\Rightarrow \frac{3I}{\mu_p W_3} = \frac{5I}{\mu_n W_1} \quad \text{or} \quad \boxed{W_3 = \frac{9}{5} W = W_4}.$$

$$V_{GST5} = V_{GST3} \Rightarrow \sqrt{\frac{I_5}{W_5/L_5}} = \sqrt{\frac{I_3}{W_3/L_3}} \Rightarrow W_5 = \frac{I_5}{I_3} W_3 = \frac{5I}{(3I/2)} \cdot \frac{9W}{5}$$

$$\Rightarrow \boxed{W_5 = W_6 = 6W}.$$

(4) Let $\frac{V_{in+} + V_{in-}}{2} = V_{incm} \Rightarrow V_{in+} = V_{incm} + 0.2 V_{GSTn}$, $V_{in-} = V_{incm} - 0.2 V_{GSTn}$.

~~$V_{incm} = V_{DS1} + V_{GSn}$ (all in active region)~~

When $V_{in+} = V_{incm} + 0.2 V_{GSTn}$, $V_{i+} = V_{DD} - |V_{GSp}| - \frac{5}{3}(0.2 V_{GST})$

$$= V_{DD} - |V_{tp}| - \frac{4}{3} V_{GST}.$$

$$V_{DS1} > 2 V_{GST1} \Rightarrow V_{DD} - |V_{tp}| - \frac{4}{3} V_{GST} - V_{snk} > V_{GST} + V_{t1} - V_{snk} - V_{tn}$$

$$= V_{GST} + V_{incm} + 0.2 V_{GST} - V_{snk} - V_{tn}$$

$$\Rightarrow V_{incm} < V_{DD} + V_{tn} - |V_{tp}| - \left(1 + \frac{1}{5} + \frac{4}{3}\right) V_{GST}$$

i.e., $\boxed{V_{incm} < V_{DD} - |V_{tp}| + V_{tn} - \frac{38}{15} V_{GST}}$.

On the lower side, assuming I_{snk} can operate down to $V_{snk} = 0$,

$V_{incm} - 0.2 V_{GSTn} > V_{tn} + V_{GST}$, or $\boxed{V_{incm} > V_{tn} + 1.2 V_{GST}}$.

Note: If $V_{snk} \neq 0$, and I_{snk} has a headroom requirement, then

$$V_{incm} > V_{tn} + 1.2 V_{GST} + V_{snk}.$$