An opamp schematic and its use as a switched-capacitor amplifier are shown below. All transistors are assumed to be biased in saturation region, and the opamp input node is properly biased. Use the following parameters: \( g_m = 1/500\Omega \) and \( r_o = 2k\Omega \) for NMOS transistor with \( W/L = 10 \) and biased with 1mA. PMOS mobility is \( \frac{1}{4} \) of NMOS mobility. Ignore all parasitics unless specified. Answer the followings assuming that \( M_1 \) through \( M_4 \) are sized to be \( W/L = 100 \), and biased with 100\( \mu \)A.

1. Estimate the DC loop gain of the feedback amplifier.

\[
g_{mn} = \frac{1}{500}\, \Omega, \quad r_{on} = 20k\,\Omega, \quad g_{mp} = \frac{1}{10k}\,\Omega, \quad r_{op} = 20k\,\Omega
\]

\[
\text{Loop gain} = \frac{1}{2} \times g_{mn} \left\{ r_{on} \left( g_{mn} \cdot r_{on} \right) \parallel \, r_{op} \left( g_{mp} \cdot r_{op} \right) \right\}
\]

\[
= \frac{1}{2} \times \frac{20k \cdot \left( \frac{20k}{500} \parallel \frac{20k}{10k} \right)}{500}
\]

\[
\approx 2.66
\]

2. Estimate the closed-loop bandwidth of the amplifier.

\[
C_L = 1pF + \frac{12pF}{2} = 1.6pF
\]

\[
\omega_L = \frac{1}{2\pi \times 500 \times 1.6pF} \approx 100\,\text{MHz}
\]
3. Assume that the total parasitic capacitance at the source of M₂ is 0.16pF, what is the phase margin?

\[ f_p \approx \frac{1}{2 \pi \times 5 \mu \Omega \times 0.16 \text{pF}} \approx 26 \text{MHz} \]

\[ \phi_m = 90^\circ - \tan^{-1} \left( \frac{1 \text{M\Omega}}{26 \text{MHz}} \right) \approx 87^\circ \]

4. Estimate the slew rate of this amplifier.

\[ SR = \frac{200 \text{mA}}{2.2 \text{pF}} \approx 91 \text{V/\mu s} \]

5. If a 1V step is applied to the input, how much does the output change after the amplifier settles?

\[ V_o = \frac{1 \text{V}}{1 + \frac{1}{266}} \approx 1 - \frac{1}{266} \approx 0.996 \text{V} \]