

Let us assume M1-7 in the following circuit are identical and operate in satuartion region with defined paramers as seen below.

a) Obtain the following variables. I_{dc} and I_{ac} are the DC and AC complenents of $I_{out.}$

$$A_{V} = \frac{V_{out}}{V_{i}} = ?$$

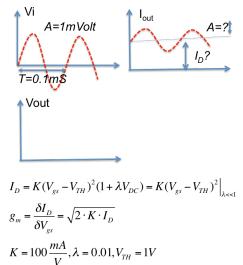
$$I_{out} = I_{dc} + I_{ac} \rightarrow I_{dc} = ?, I_{ac} = ?$$

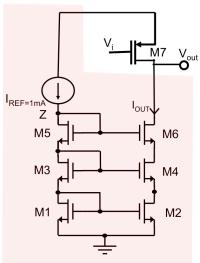
$$\frac{V_{out}}{V_{in}} = -\frac{Z_{6} \| r_{o7}}{\frac{1}{g_{m}}} = -g_{m} r_{o7} \approx -1400$$

$$I_{dc} = 1mA, I_{ac} = \frac{V_{out}}{Z_{D6}} = \frac{-1.4 \cdot 10^{-3} \cdot \sin(\frac{2\pi}{T}t)}{\approx g_{m}^{2} r_{o}^{3}}$$

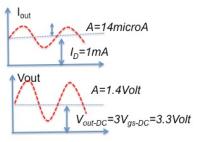
$$\rightarrow I_{ac} = -A \sin(\frac{2\pi}{T}t), T = 0.1ms, A = \frac{g_{m} r_{o}}{g_{m} r_{o}^{3}} = \frac{10^{-3}}{g_{m} r_{o}^{2}} = 7.1 \times 10^{-9} A$$

b) As per above calculations, draw V_{out} and I_{out} signal. (Hint: V_{out} has two ac and dc compenents).

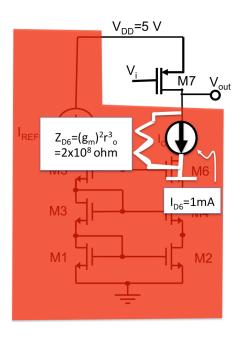




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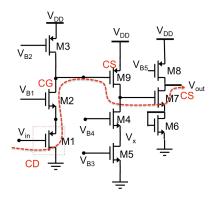


c) Draw a simplified version of above circuit by replacing the highlighted circuitry with a voltage source and a resistor.



- 2) Let us assume M1-9 are identical and similar to the MOSFET in question 1. Also all MOSFET operates in saturation region. Assume $V_{\rm B1-}$ are dc voltages. Also use the following terminology. The drain current, transconductance, Output resistance of MOSFET (Mi) are $I_{\rm di}$, $g_{\rm mi}$ and $r_{\rm oi}$ respectively.
 - a) Draw the ac signal pathway (a line connect input to output through transistors). Then express the number of single stages (4) in this voltage amplifier? Close to each stage write if the amplifier is Common Drain, Common Source or Common Gate.

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b) Obtain the voltage gain of each stage and then the total voltage gain $V_{\text{out}}/V_{\text{in}}$.

$$A_{stage-1} = -\frac{\frac{1}{g_{m2}}}{\frac{1}{g_{m1}}}$$

$$A_{stage-2} = -\frac{r_{o3} \| [r_{o1}(1 + g_{m2} \| \frac{1}{g_{m1}}) + \frac{1}{g_{m1}}]}{\frac{1}{g_{m3}}}$$

$$A_{stage-3} = -\frac{r_{o9} \| [r_{o4}(1 + g_{m4} \| r_{o5}) + r_{o5}]}{\frac{1}{g_{m9}}}$$

$$A_{stage-4} = -\frac{r_{o8} \| [r_{o7}(1 + g_{m7} \| \frac{1}{g_{m6}}) + \frac{1}{g_{m6}}]}{\frac{1}{g_{m7}}}$$

$$A_{stage-Total} = A_{stage-1} \times A_{stage-2} \times A_{stage-3} \times A_{stage-4}$$