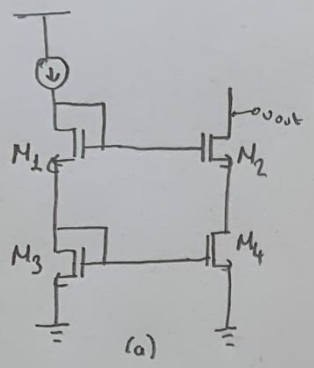
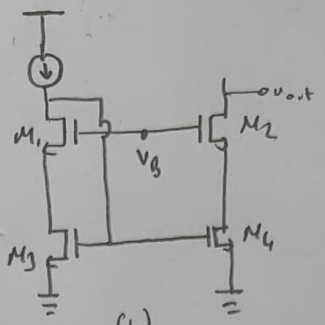
THE-I Solutions

1.



(a)



(b)

* $R_{out(a)} = R_{out(b)} = r_{O4} + r_{O2} + g_{m2} r_{O2} r_{O4}$

* $V_{out(a)} \geq 2V_{GS} - V_{TN} \Rightarrow V_{out(a)min} = 2V_{GS} - V_{TN}$

* $V_{out(b)} \geq V_B - V_{TN}$

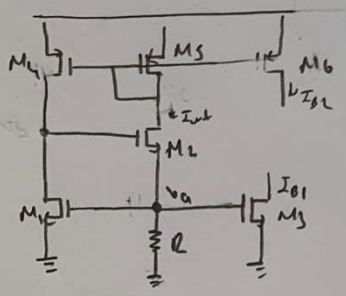
$2V_{GS} - V_{TN} \leq V_B \leq V_{TN} + V_{GS}$

To obtain max swing $V_{out min}$ must be minimized.

$V_{out(b)min} = 2V_{GS} - 2V_{TN}$

* - Both have some output resistance
  - Modified version has larger swing (V_{TN})
  - Modified version requires external biasing.

2.



* $V_a = V_{GS1} + V_{TN}$

$K_N = \mu_n \cdot \frac{W}{L} C_{ox}$

$K_P = \mu_P \frac{W}{L} C_{ox}$ ...

* $I_{D1} = \frac{1}{2} K_{N1} V_{GS1}^2$
  $I_{D4} = \frac{1}{2} K_{P4} V_{SG4}^2$
  $I_{out} = \frac{1}{2} K_{P5} V_{SG5}^2$

  $I_{D1} = I_{D4}$, $I_{D4} = \frac{K_{P5}}{K_{P5}} I_{out}$ $\Rightarrow V_{GS1} = \sqrt{\frac{2 I_{out}}{K_{N1}} \frac{K_{P4}}{K_{P5}}}$

* $V_a = V_{GS1} + V_{TN} = I_{out} R$

$I_{out} = \left(\sqrt{\frac{2 I_{out}}{K_{N1}} \frac{K_{P4}}{K_{P5}}} + V_{TN} \right) \cdot \frac{1}{R}$

$I_{out} = \left(\frac{\sqrt{\frac{2K_{P4}}{K_{N1}K_{P5}}} + \sqrt{\frac{2K_{P4}}{K_{N1}K_{P5}} + 4RV_{TN}}}{2R} \right)^2$

$I_{D3} = I_{B1} = \frac{K_{N3}}{K_{N1}} I_{D1} = \frac{K_{N3}}{K_{N1}} \cdot \frac{K_{P5}}{K_{P5}} I_{out}$

$I_{B1} = \frac{K_{N3} \cdot K_{P5}}{K_{N1} \cdot K_{P5}} \cdot \left(\frac{\sqrt{\frac{2K_{P4}}{K_{N1}K_{P5}}} + \sqrt{\frac{2K_{P4}}{K_{N1}K_{P5}} + 4RV_{TN}}}{2R} \right)^2$

$I_{D6} = I_{B2} = \frac{K_{P6}}{K_{P5}} \cdot I_{out}$

$I_{B2} = \frac{K_{P6}}{K_{P5}} \left(\frac{\sqrt{\frac{2K_{P4}}{K_{N1}K_{P5}}} + \sqrt{\frac{2K_{P4}}{K_{N1}K_{P5}} + 4RV_{TN}}}{2R} \right)^2$