

## 8.1 Current source

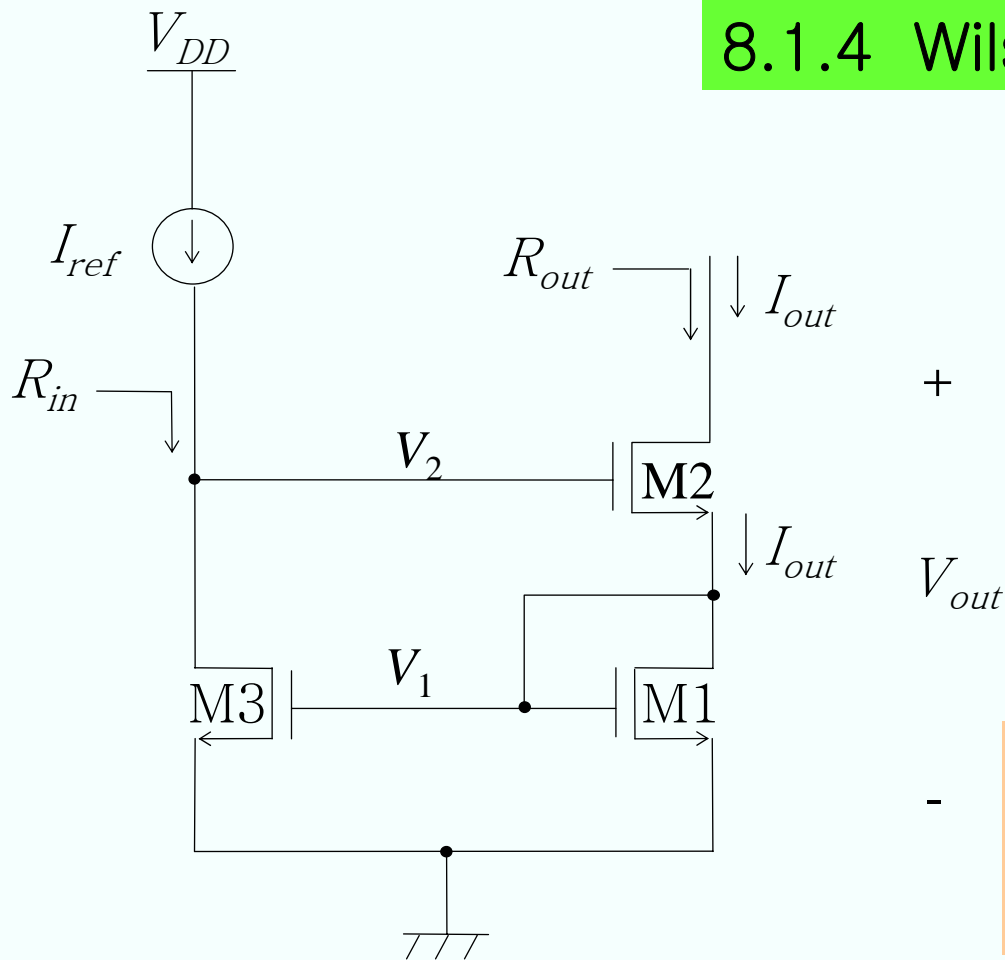
6. Wilson current source

7. Active cascode current source 1, 2, 3, 4, 5

8. Active current mirror

9. Matching of current source

## 8.1.4 Wilson current source

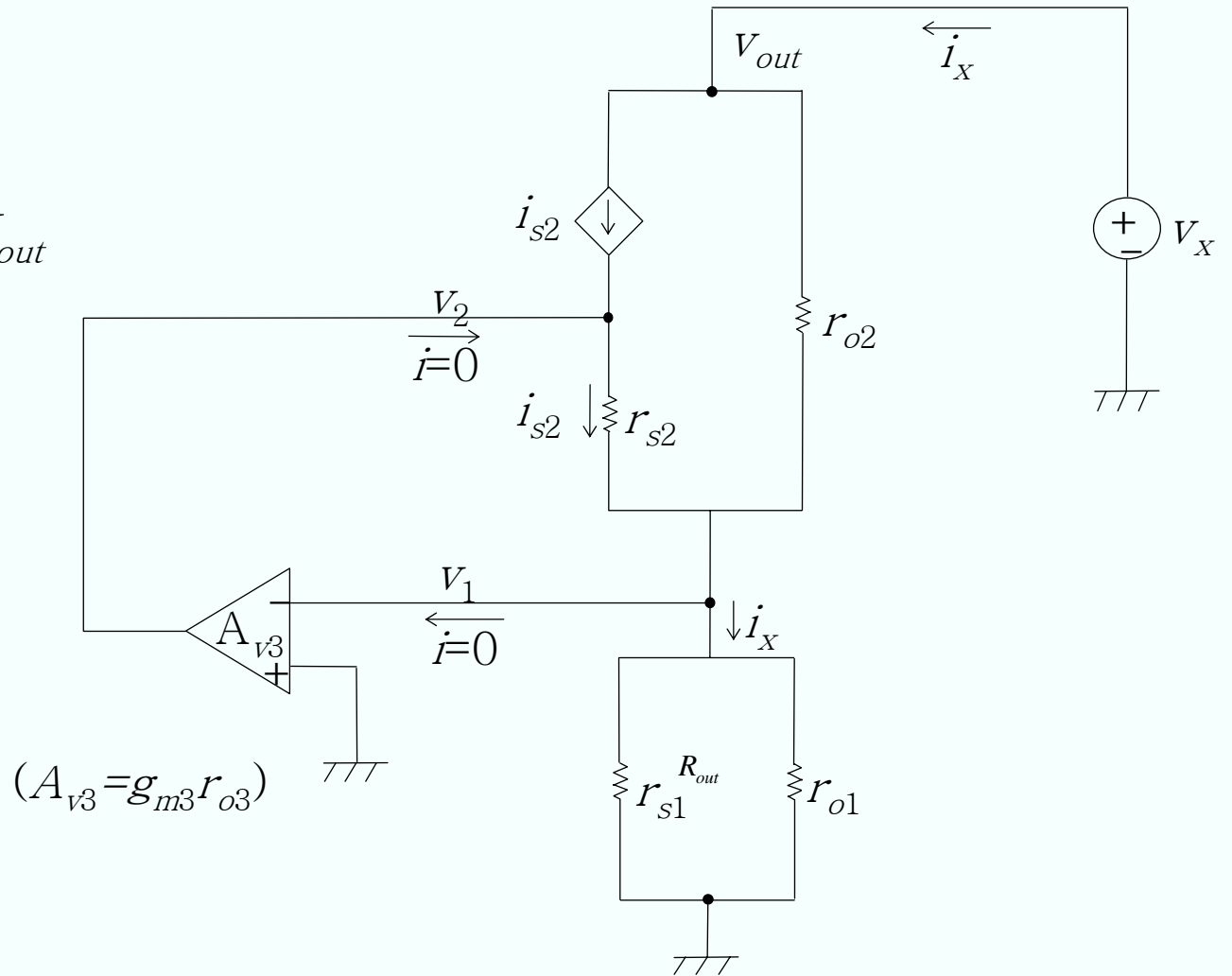
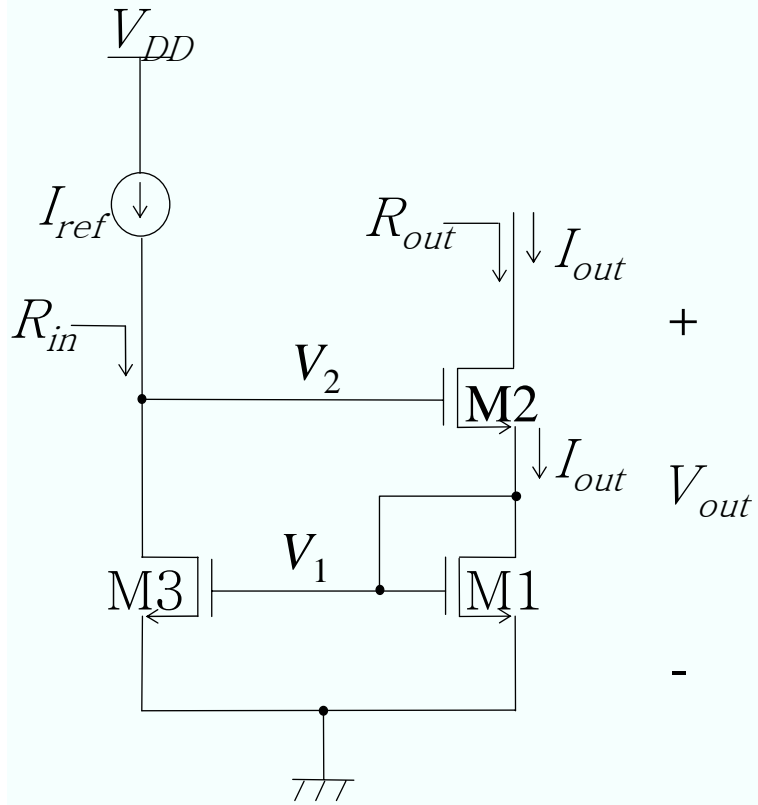


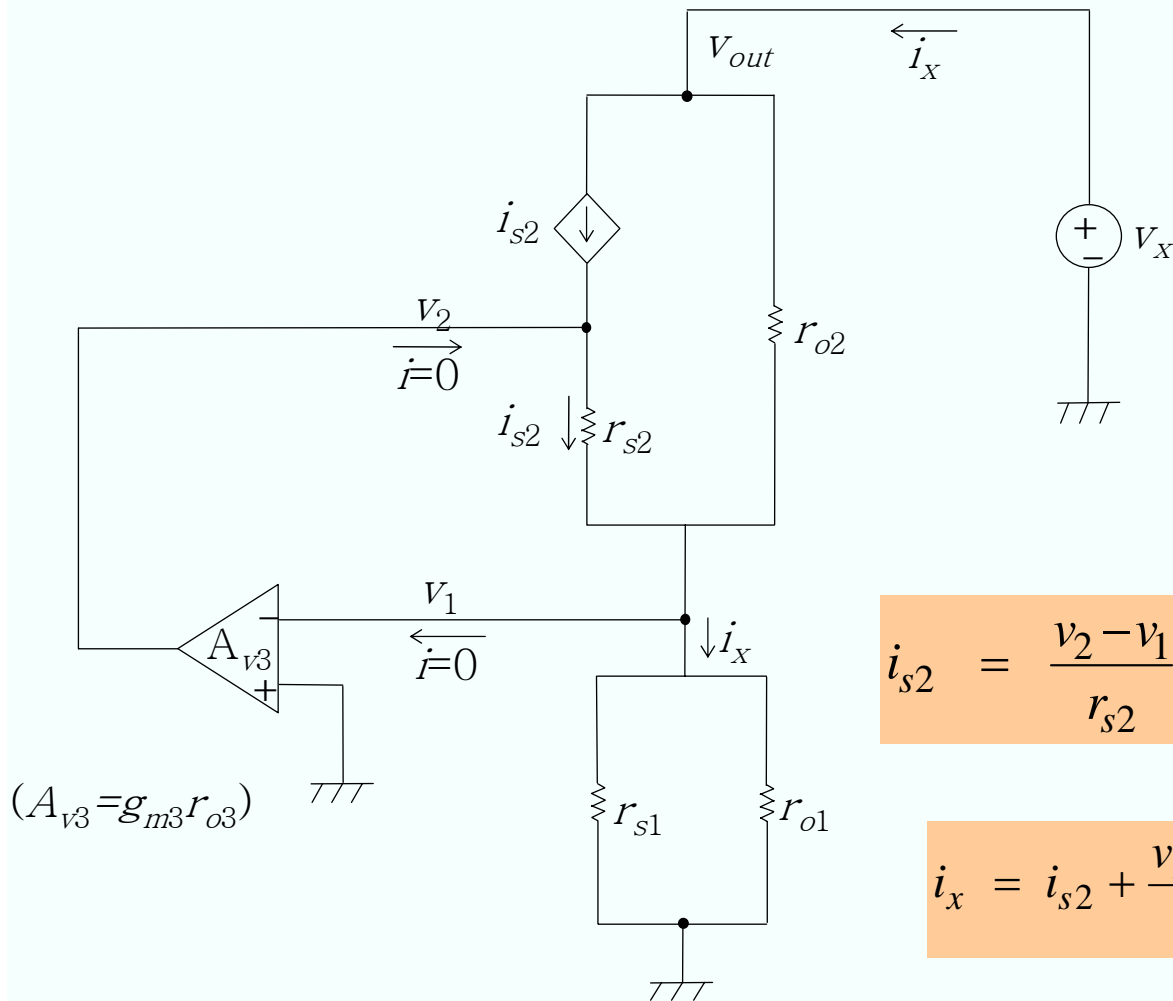
$$I_{out} = I_{ref} \cdot \frac{g_{m1}}{g_{m3}} = I_{ref} \cdot \frac{(W/L)_1}{(W/L)_3}$$

$$V_{DS3} = V_{GS2} + V_{GS1}$$

$$V_{DS1} = V_{GS1}$$

→ Current gain  $I_{out}/I_{ref} < 1$

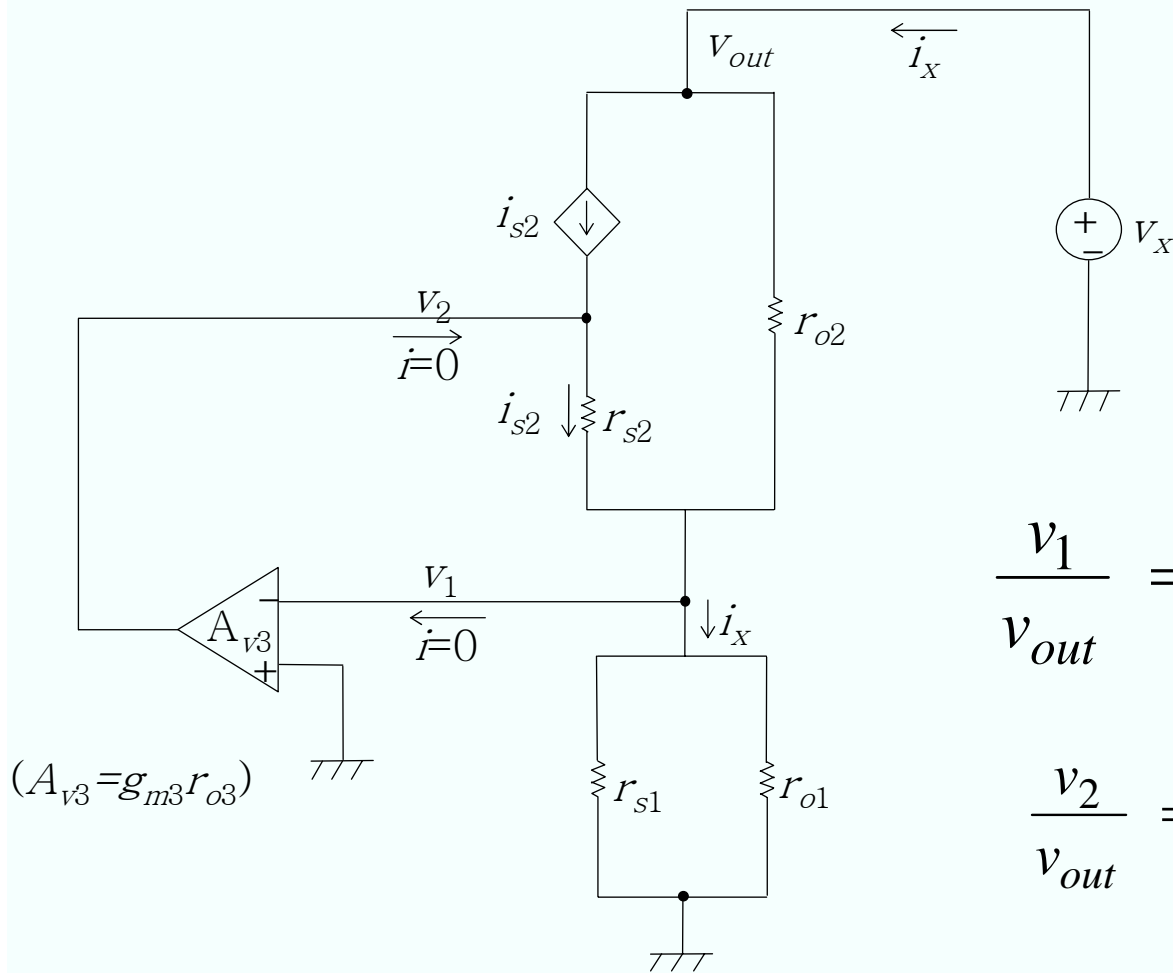




$$i_{s2} = \frac{v_2 - v_1}{r_{s2}} = -(A_{v3} + 1) \cdot \frac{v_1}{r_{s2}} = -(A_{v3} + 1) \cdot \frac{r_{s1}}{r_{s2}} \cdot i_x$$

$$i_x = i_{s2} + \frac{v_x - v_1}{r_{o2}} = -(A_{v3} + 1) \cdot i_x \cdot \frac{r_{s1}}{r_{s2}} + \frac{v_x - r_{s1} \cdot i_x}{r_{o2}}$$

$$R_{out} = \frac{v_x}{i_x} = (A_{v3} + 1) \cdot (g_{m2} r_{o2}) \cdot r_{s1} + r_{o2} + r_{s1} \approx A_{v3} \cdot (g_{m2} r_{o2}) \cdot r_{s1} = (g_{m3} r_{o3}) \cdot (g_{m2} r_{o2}) \cdot r_{s1}$$

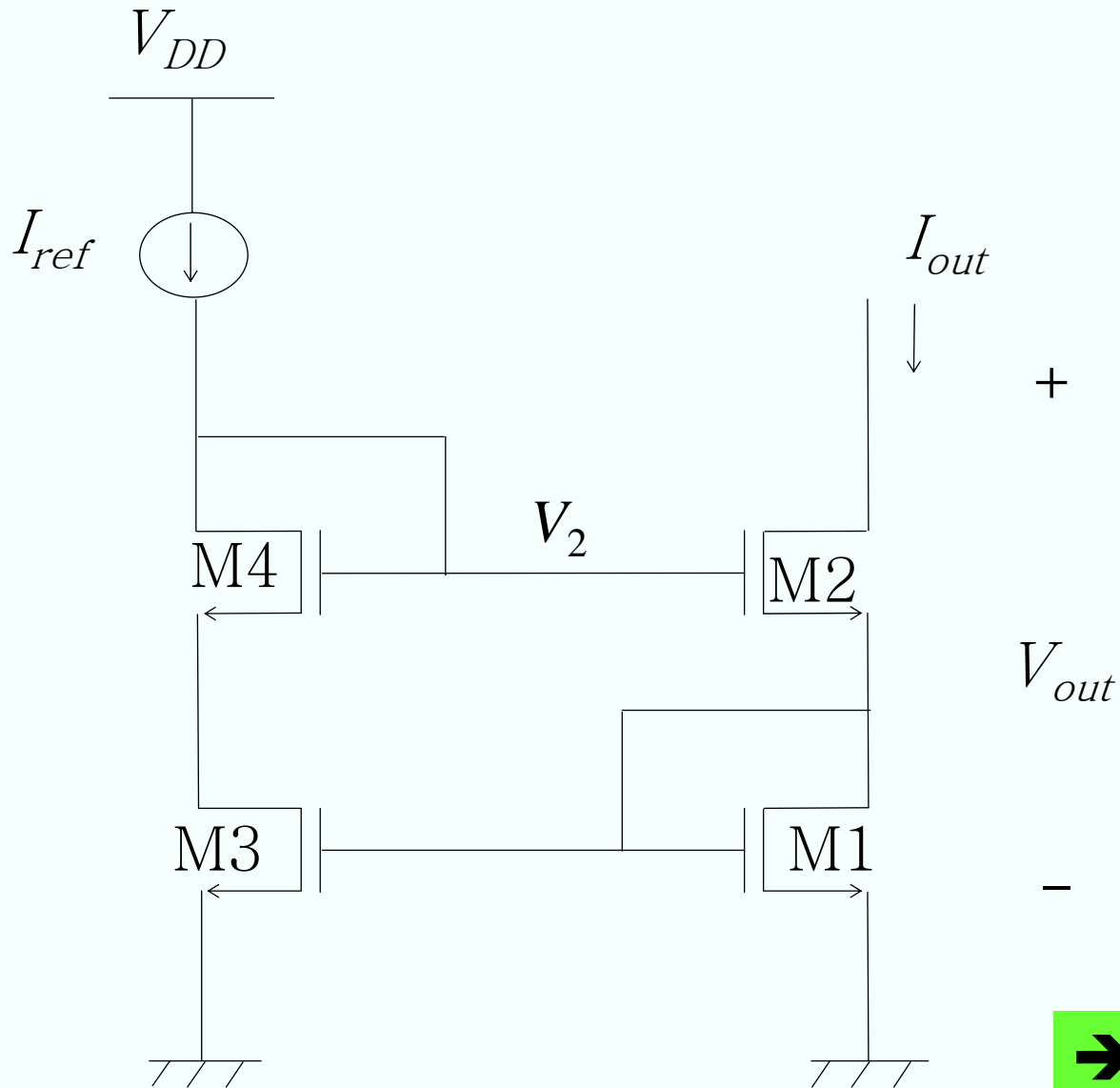


$$\frac{v_1}{v_{out}} = \frac{r_{s1}}{R_{out}} \approx \frac{1}{(g_{m3}r_{o3}) \cdot (g_{m2}r_{o2})}$$

$$\frac{v_2}{v_{out}} = -A_{v3} \cdot \frac{v_1}{v_{out}} = -\frac{1}{g_{m2}r_{o2}}$$

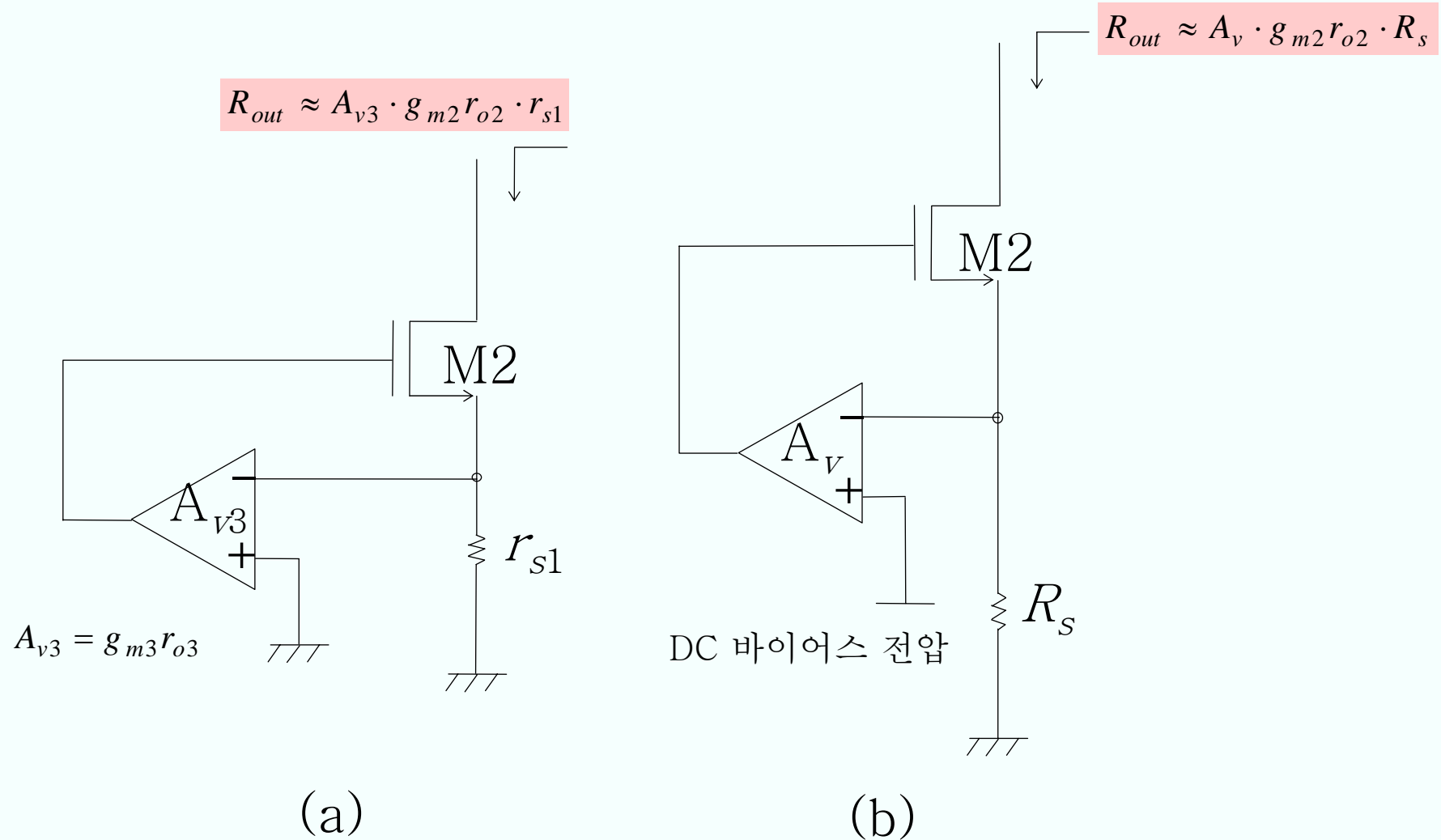
$$R_{in} = \frac{r_{o3}}{\text{loop gain}} = \frac{r_{o3}}{g_{m3}r_{o3} \cdot \left(\frac{g_{m2}}{g_{m1} + g_{m2}}\right)}$$

$$R_{in} = r_{s3} \cdot \left(1 + \frac{g_{m1}}{g_{m2}}\right)$$

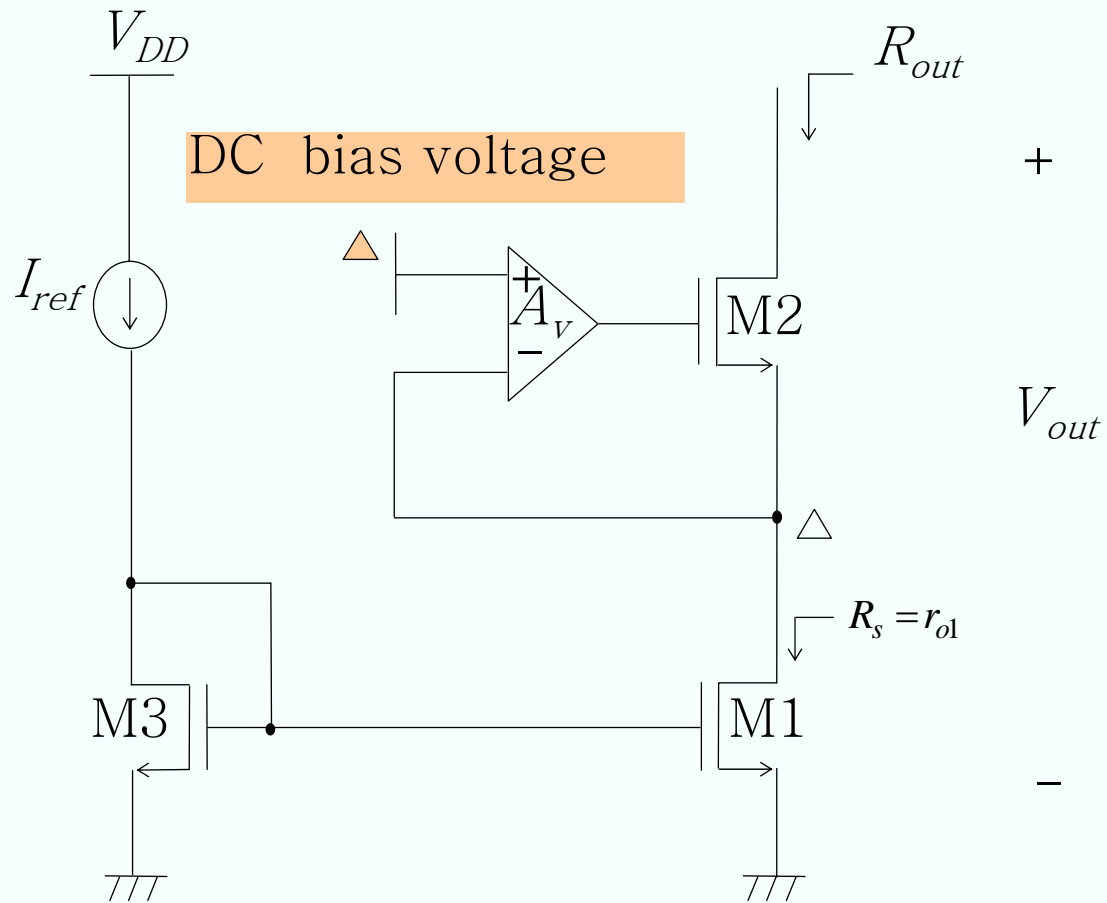


$$V_{DS1} = V_{DS3}$$

→ Current gain  $I_{out}/I_{ref} = 1$



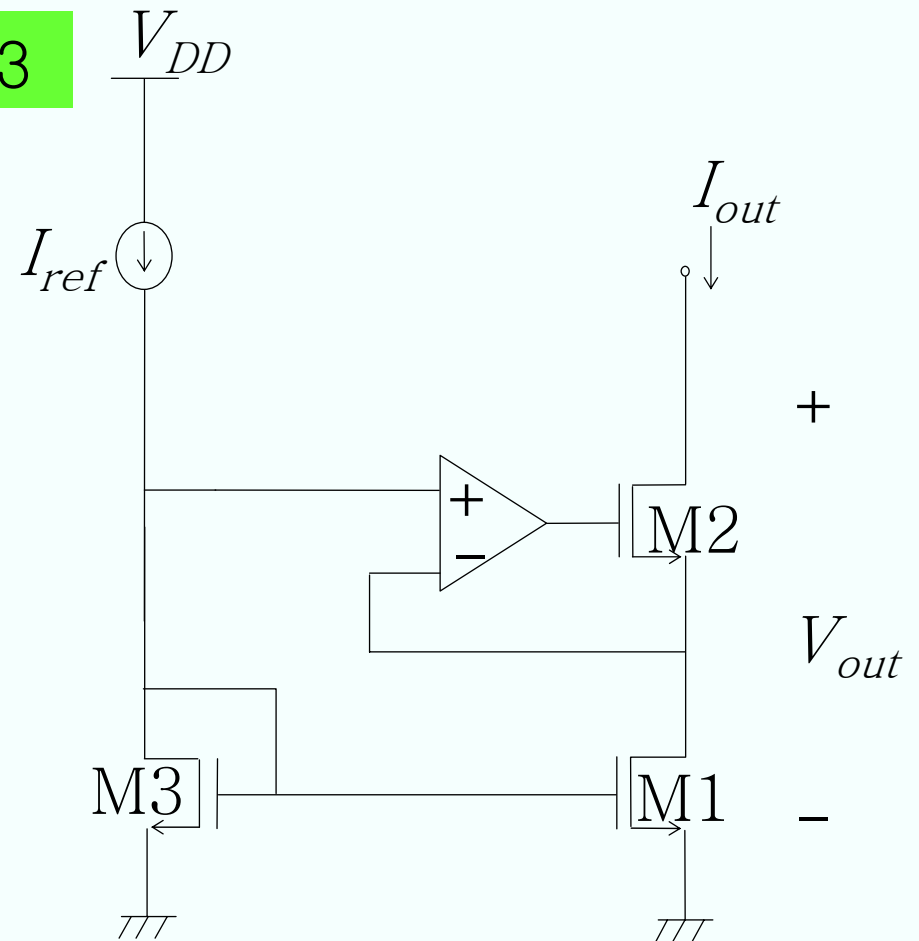
**Fig 8.1.11** active cascode current source (a) ckt 1(Wilson current source) (b) ckt 2

**Fig 8.1.12** Active cascode current source circuit 2

## Active cascode current source 3

$$(W/L)_1 = (W/L)_2 = (W/L)_3$$

$$V_{DS1} = V_{GS3} = \Delta + V_{TH}$$



$$V_{out} \geq V_{DS1} + V_{DS2} \geq V_{DS1} + \Delta \geq 2\Delta + V_{TH}$$

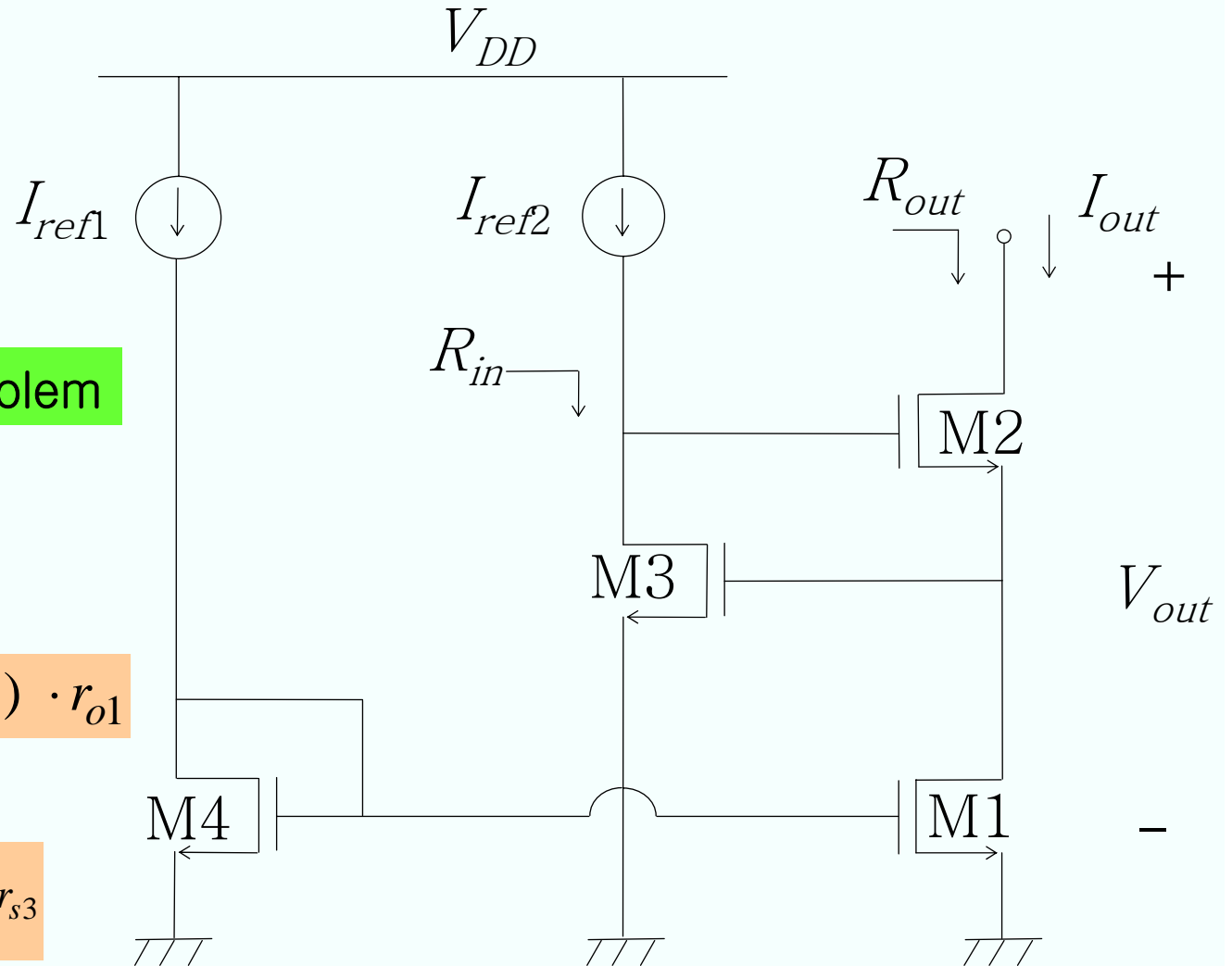
$$V_{out} \cong V_{GS2} + V_{GS3} - V_{TH}$$

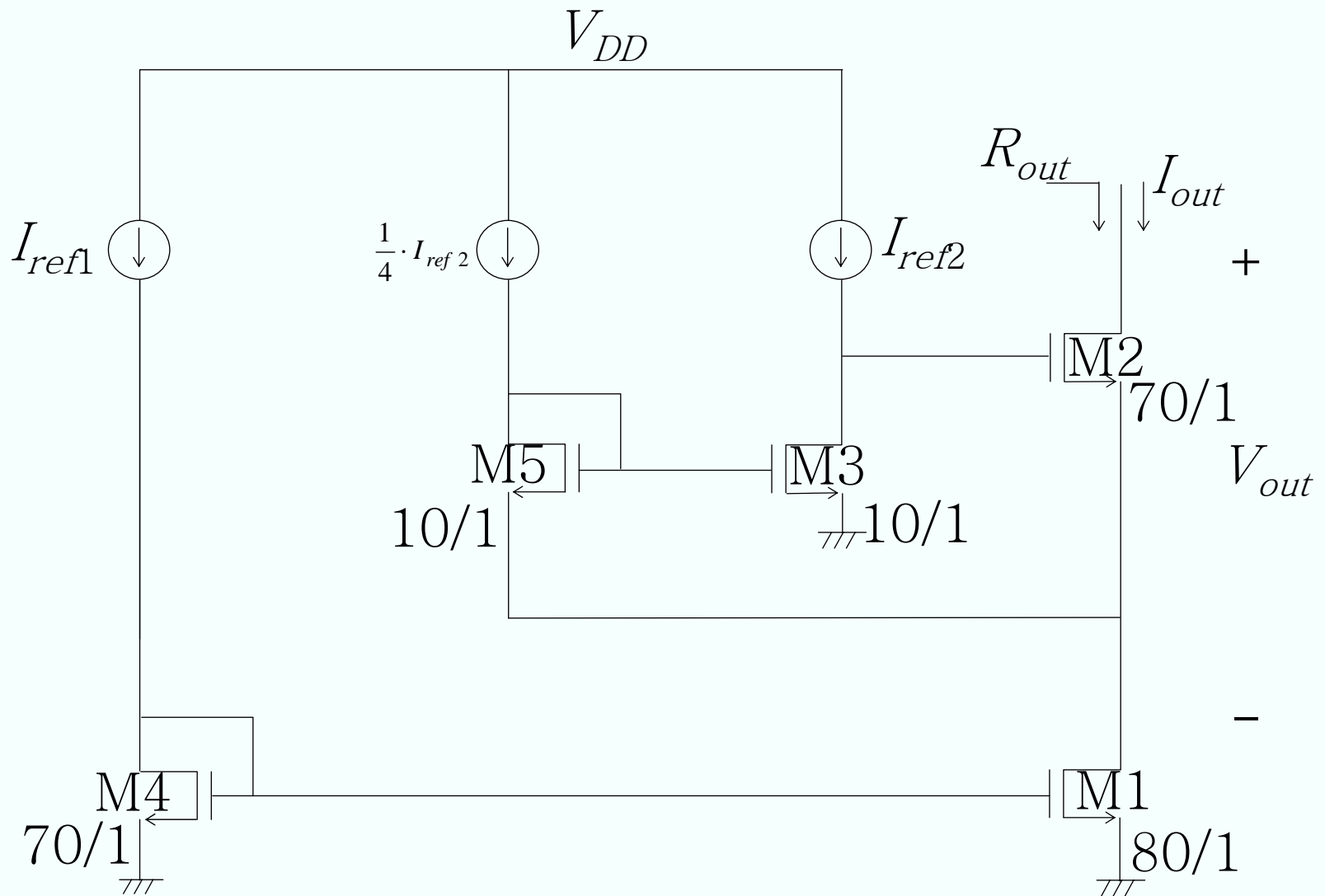
$$V_{out} \cong 2\Delta + V_{TH} \quad \text{Problem}$$

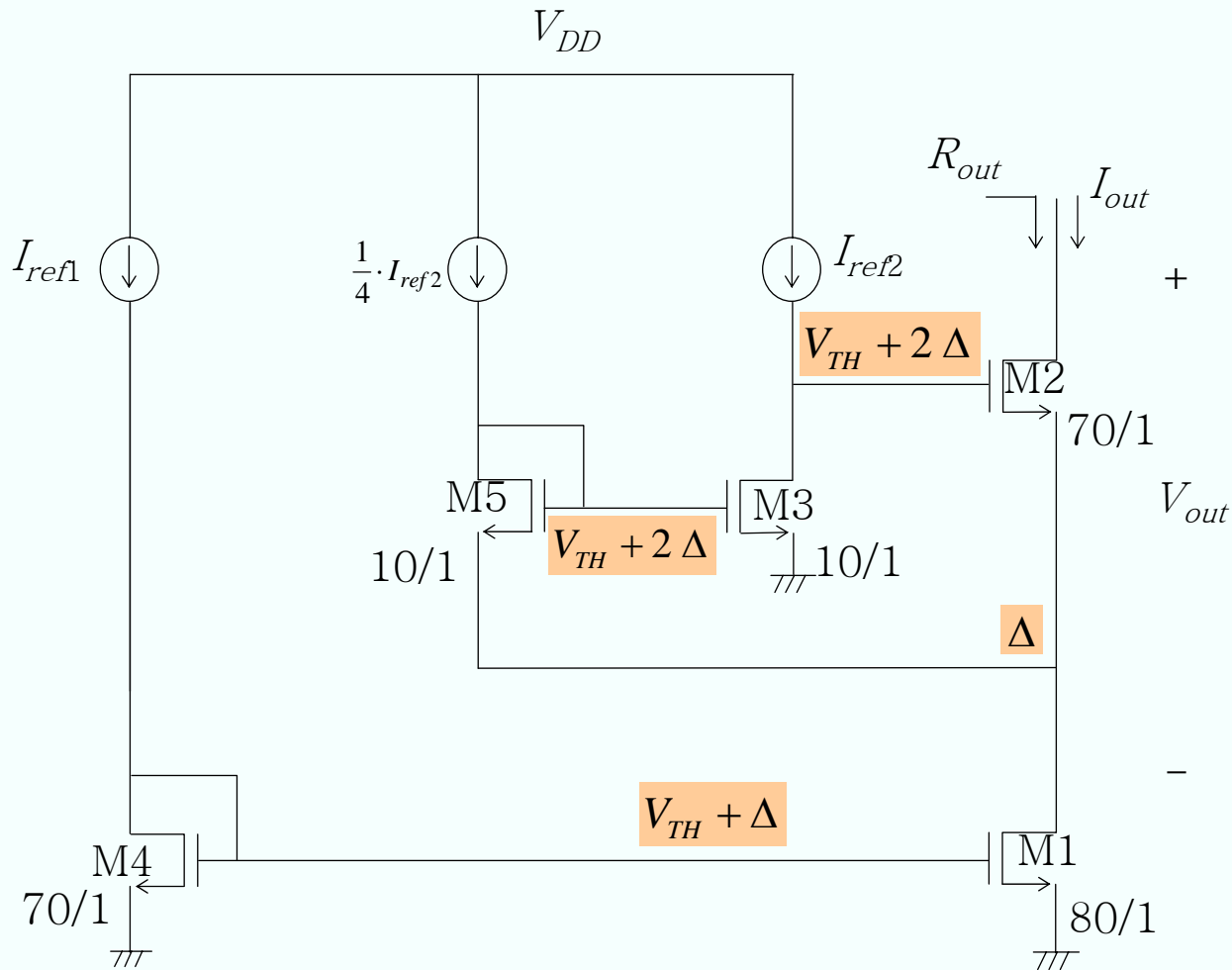
High-speed operation

$$R_{out} \approx (g_{m2}r_{o2}) \cdot (g_{m3}r_{o3}) \cdot r_{o1}$$

$$R_{in} \approx \frac{r_{o3}}{(\text{loop gain})} = \frac{1}{g_{m3}} = r_{s3}$$







Target

$$V_{OUT} \geq 2\Delta$$

$$I_{out} = I_{ref1}$$

$$V_{DSAT1} = V_{DSAT2} = \frac{1}{2} V_{DSAT3} = V_{DSAT4} = V_{DSAT5} = \Delta$$

$$V_{OUT} \geq 2\Delta$$

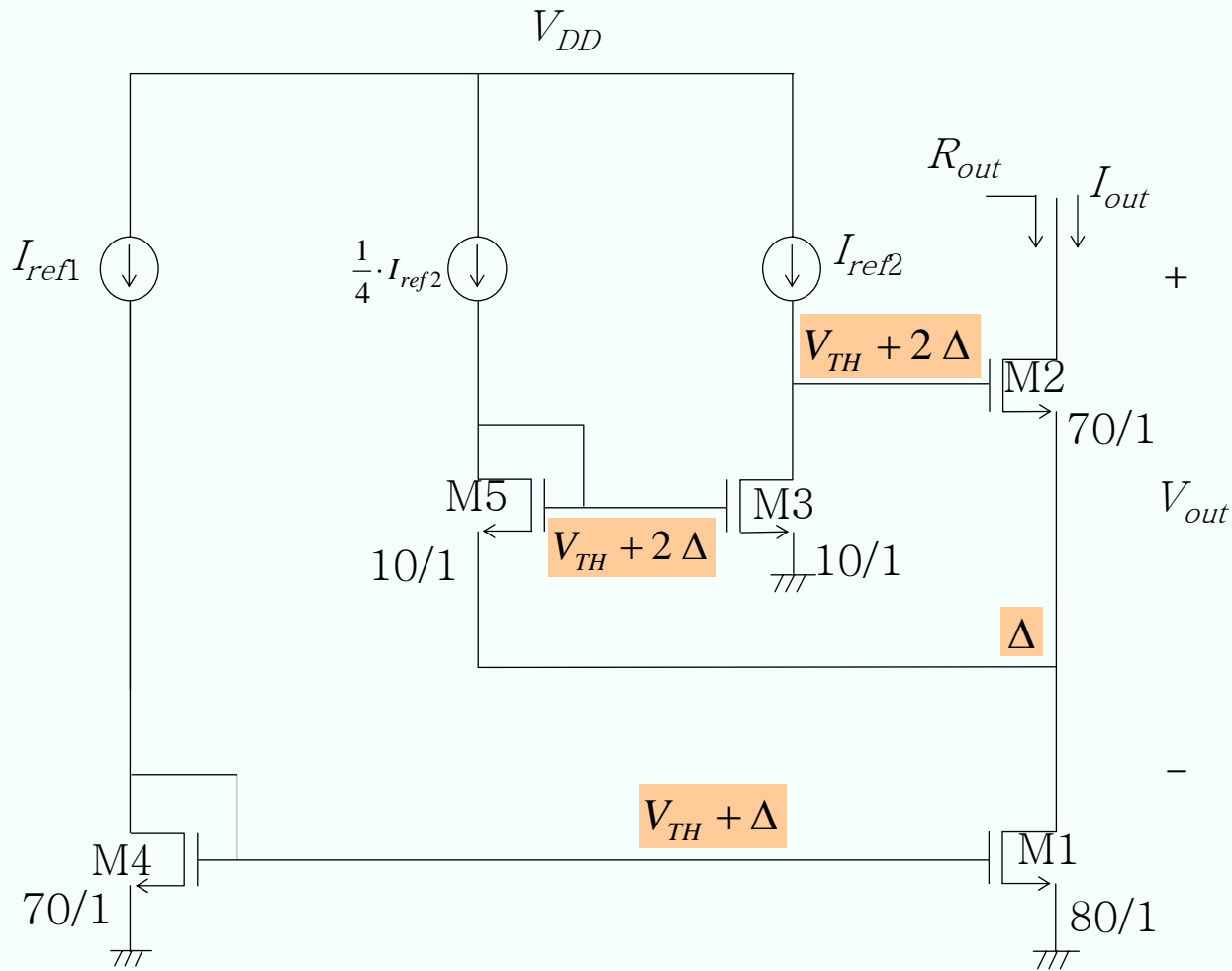
$$V_{DSAT1} = V_{DSAT2} = \frac{1}{2} V_{DSAT3} = V_{DSAT4} = V_{DSAT5} = \Delta$$

$$\frac{I_{out} + \frac{1}{4} I_{ref2}}{(W/L)_1} = \frac{I_{out}}{(W/L)_2} = \frac{\frac{1}{4} I_{ref2}}{(W/L)_3} = \frac{I_{ref1}}{(W/L)_4} = \frac{\frac{1}{4} \cdot I_{ref2}}{(W/L)_5} = \frac{1}{2} \mu C_{ox} \Delta^2$$

$$\frac{I_{out} + \frac{1}{4} I_{ref 2}}{(W/L)_1} = \frac{I_{out}}{(W/L)_2} = \frac{\frac{1}{4} I_{ref 2}}{(W/L)_3} = \frac{I_{ref 1}}{(W/L)_4} = \frac{\frac{1}{4} \cdot I_{ref 2}}{(W/L)_5}$$

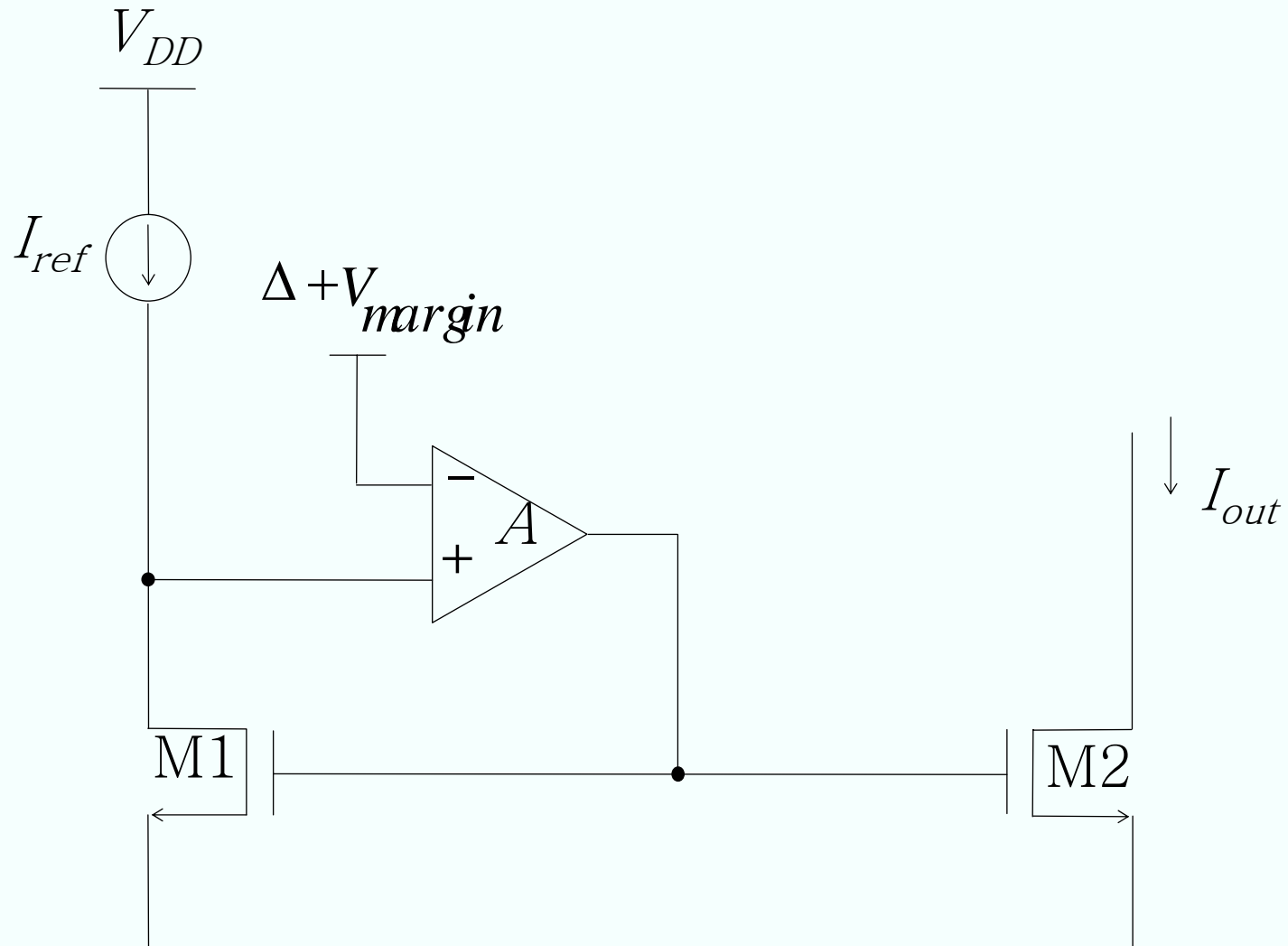
$$I_{ref 1} = I_{out} \quad \text{let} \quad I_{ref 1} = \frac{7}{4} \cdot I_{ref 2}$$

$$\rightarrow \frac{(W/L)_1}{8} = \frac{(W/L)_2}{7} = \frac{(W/L)_3}{1} = \frac{(W/L)_4}{7} = \frac{(W/L)_5}{1}$$

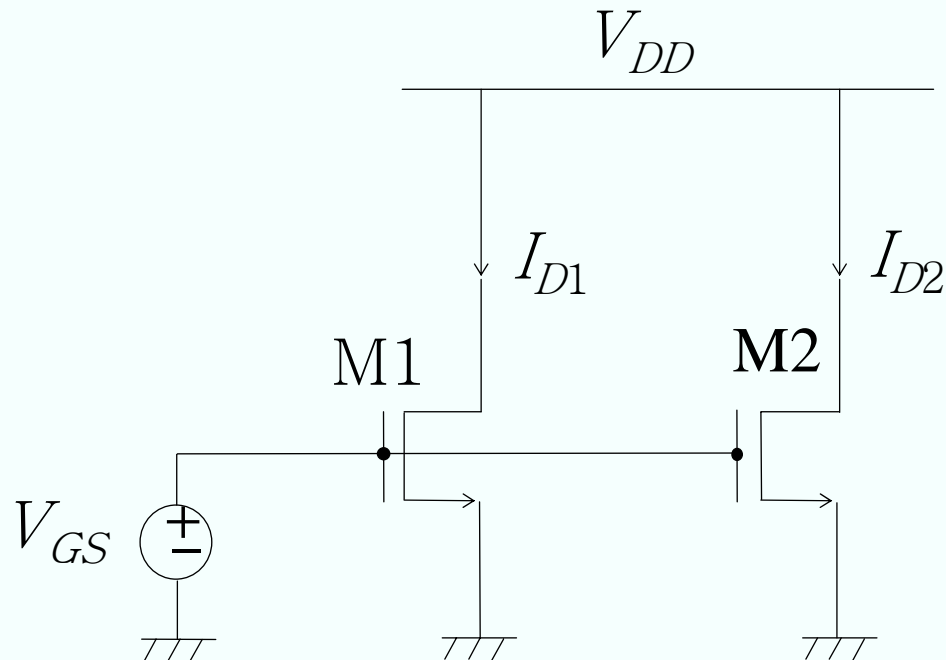


$$R_{out} \approx A_{v3} \cdot g_{m2} r_{o2} \cdot r_{o1} = (g_{m3} r_{o3}) \cdot (g_{m2} r_{o2}) \cdot r_{o1}$$

## 8.1.6 active current mirror (\*)



## 8.1.7 Matching of current source



$$I_D = \frac{1}{2} \mu_n C_{ox} \cdot \left( \frac{W}{L} \right) \cdot (V_{GS} - V_{TH})^2$$

$$\ln(I_D) = \ln\left(\frac{1}{2} \mu_n C_{ox}\right) + \ln\left(\frac{W}{L}\right) + 2 \ln(V_{GS} - V_{TH})$$

$$\frac{\Delta I_{D1,2}}{I_{D1,2}} = \frac{\Delta \left( \frac{W}{L} \right)_{1,2}}{\left( \frac{W}{L} \right)_{1,2}} - \frac{\Delta V_{TH1,2}}{\left( \frac{V_{GS} - V_{TH1,2}}{2} \right)}$$