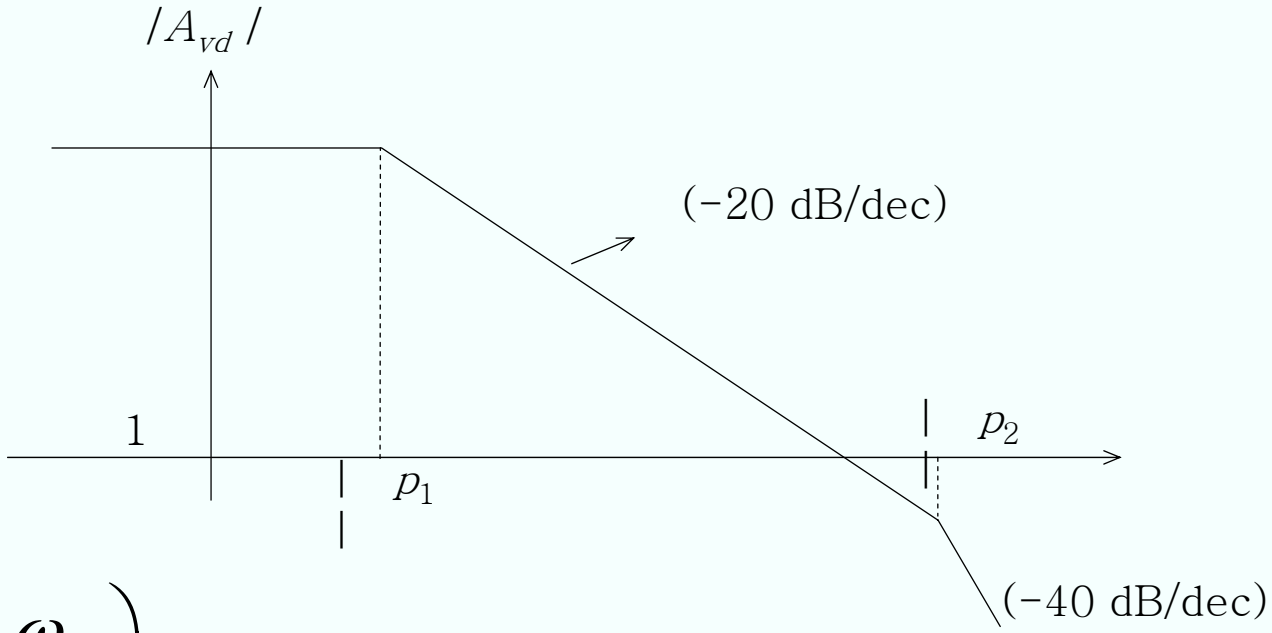
Review: Phase margin of 2-pole amp

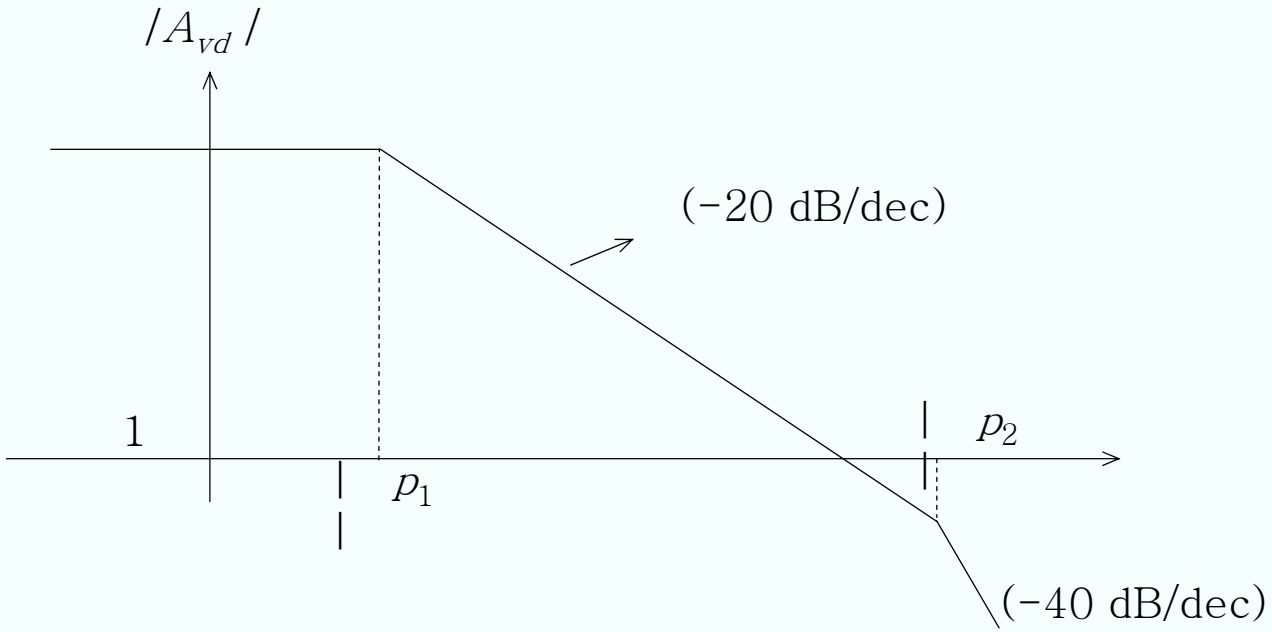


$$PM = 180 - 90 - \tan^{-1}\left(\frac{\omega_T}{p2}\right)$$

$$\approx 180 - 90 - 45 - 45 \cdot \log_{10}\frac{\omega_T}{p2}$$

$$= 45 \cdot \log_{10}\frac{10 \cdot p2}{\omega_T}$$

Folded cascode OP amp: Frequency response



$$A_{vd} = g_{m1}R_o \qquad |p_1| = \frac{1}{R_o C_L} \qquad \omega_T = \frac{g_{m1}}{C_L} \qquad |p_2| = \frac{1}{r_{s6}C_6}$$

increase CL ➔ decrease p1 & w_T, no effect on p2

➔ Increase phase margin (PM)

2-stage OP amp: Frequency response

Parameters	$\lvert A_{dv}(0)\rvert$	p_1	p_2	z_1	ω_T
Equations	$G_{m1}R_{o1}\cdot G_{m2}R_{o2}$	$\dfrac{-1}{R_{o1}\cdot G_{m2}R_{o2}\cdot C_C}$	$-\dfrac{G_{m2}}{C_L}$	$+\dfrac{G_{m2}}{C_C}$	$\dfrac{G_{m1}}{C_C}$

$$z_1 = \frac{G_{m2}}{C_C}\cdot\frac{1}{1-G_{m2}\cdot R_Z}$$

increase CL ➔ decrease p2, no effect on w_T

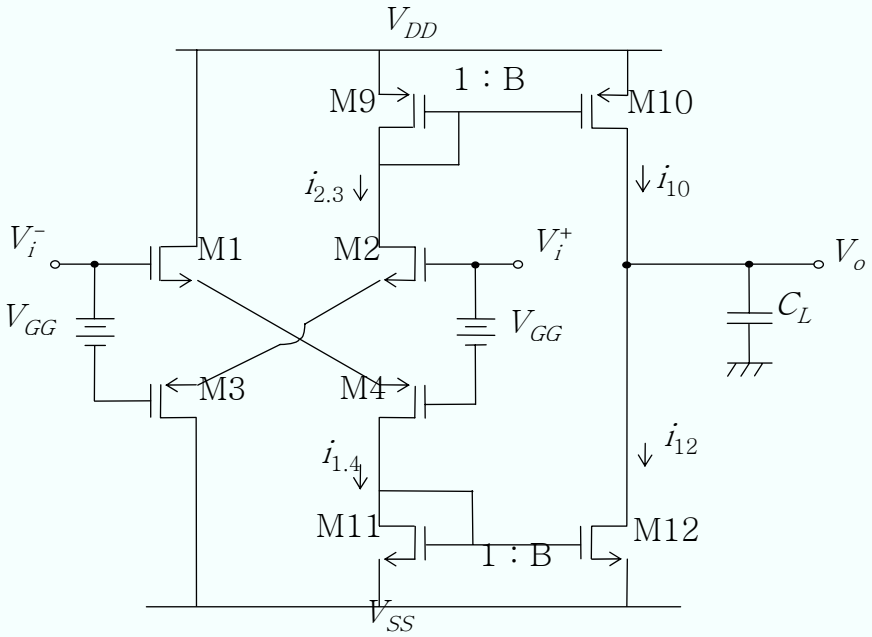
➔ Decrease phase margin (PM)

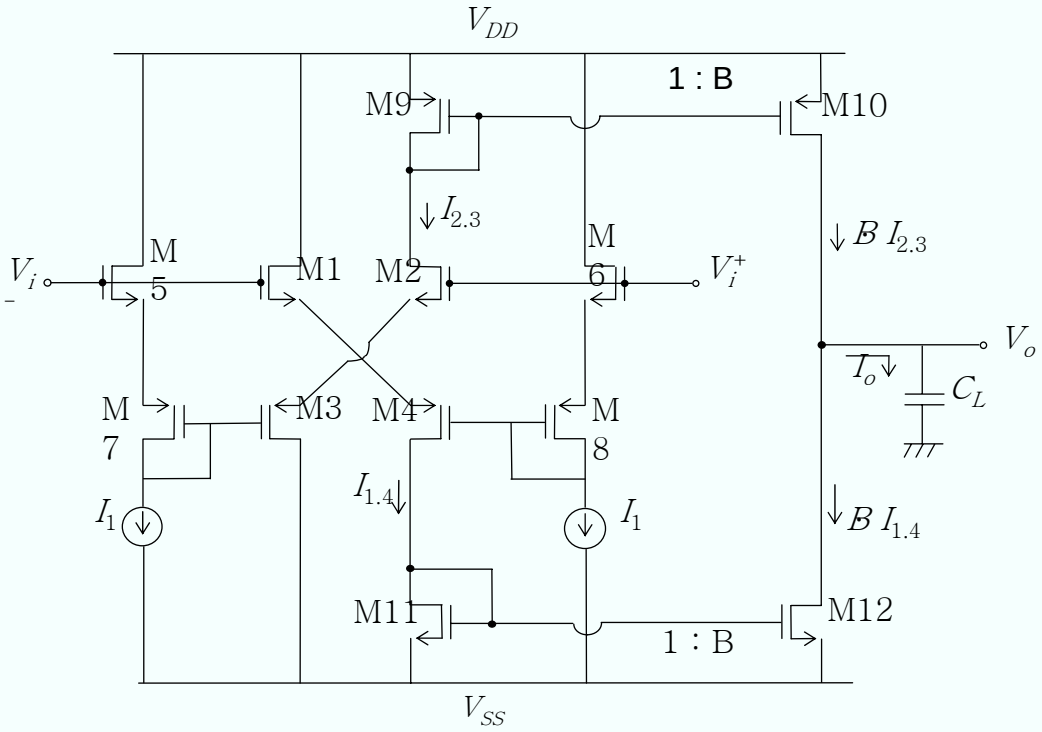
(1) Class AB input OP amp
for large slew rate

(2) Class AB output stage
for low power at small input

(3) Current amplifier

Class AB input OP amp

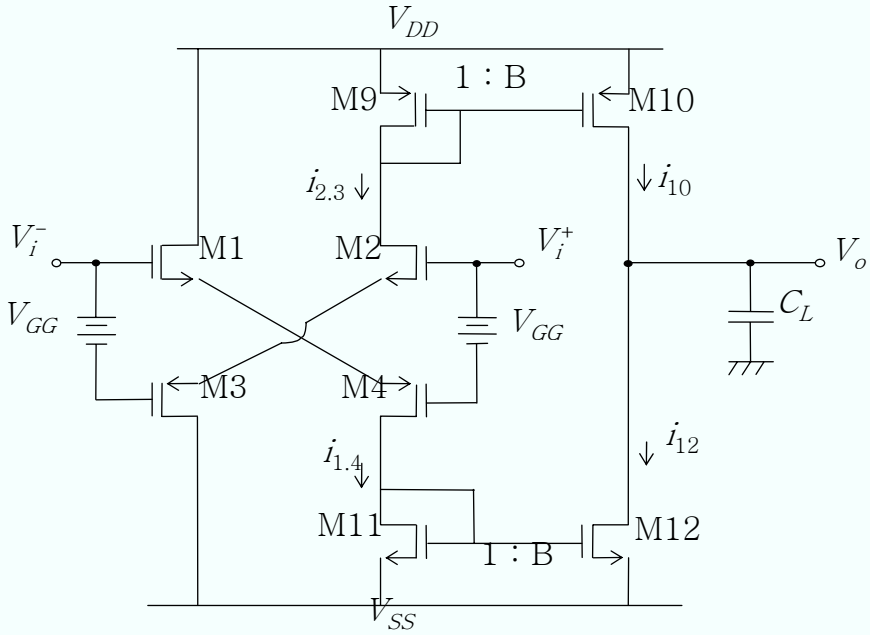




For Large Slew Rate

With bias circuit

Class AB input OP amp



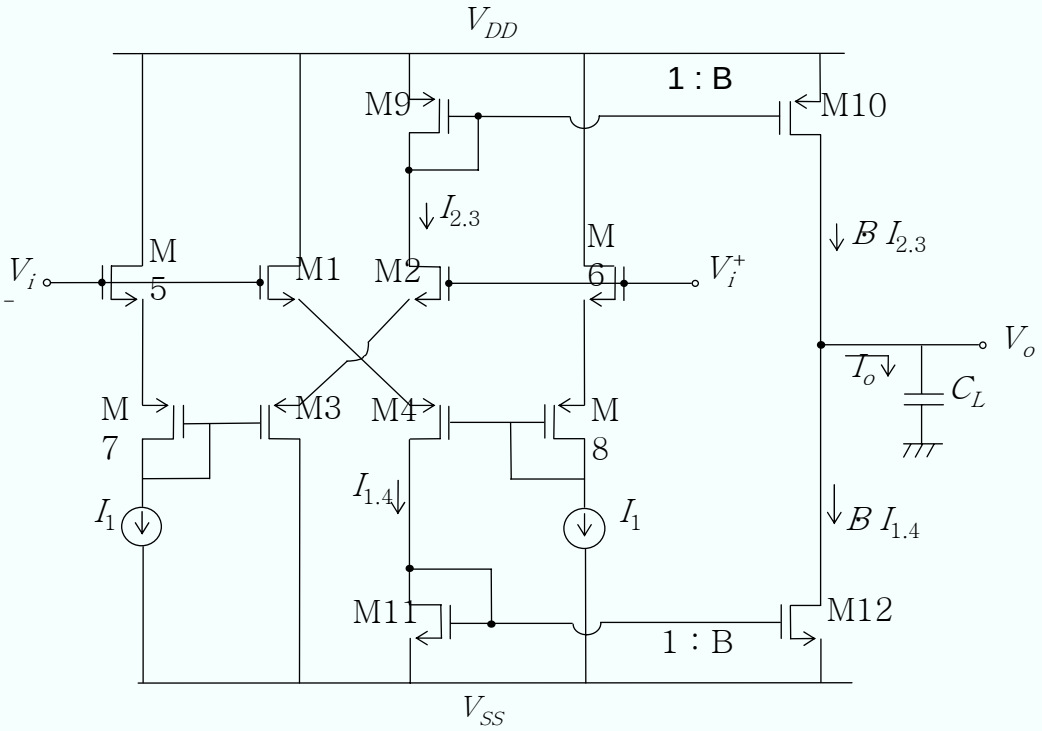
$$i_{2.3} = \frac{1}{r_{s2} + r_{s3}} \cdot (v_i^+ - v_i^-)$$

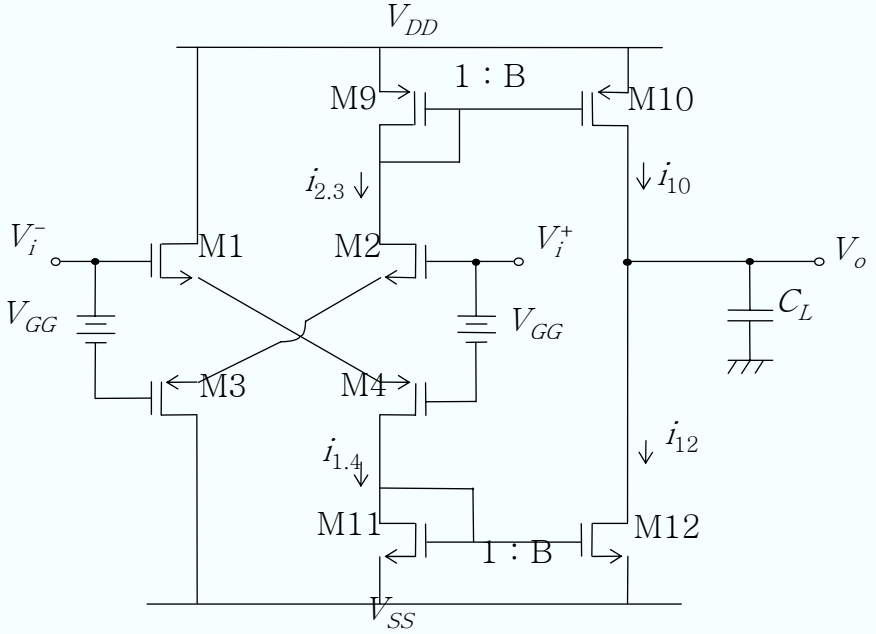
$$i_{10} = B \cdot i_{2.3} = \frac{B}{r_{s2} + r_{s3}} \cdot (v_i^+ - v_i^-)$$

$$i_{12} = B \cdot i_{1.4} = \frac{B}{r_{s1} + r_{s4}} \cdot (v_i^- - v_i^+)$$

$$v_o = (i_{10} - i_{12}) \cdot \left(r_{o10} \| r_{o12}\right) = 2B \cdot \frac{r_{o10} \| r_{o12}}{r_{s1} + r_{s4}} \cdot (v_i^+ - v_i^-)$$

Class AB input OP amp





$$V_{GG} = V_{THn} + \sqrt{\frac{2I_B}{\mu_n C_{ox}} \cdot \left(\frac{L}{W}\right)_1} + \left|V_{THp}\right| + \sqrt{\frac{2I_B}{\mu_p C_{ox}} \cdot \left(\frac{L}{W}\right)_4}$$

$$\sqrt{\frac{2I_{1.4}}{\mu_n C_{ox}} \cdot \left(\frac{L}{W}\right)_1} + \sqrt{\frac{2I_{1.4}}{\mu_p C_{ox}} \cdot \left(\frac{L}{W}\right)_4} + V_{THn} + \left|V_{THp}\right| = V_{GG} - \left(V_i^+ - V_i^-\right)$$

$(V_i^+ - V_i^-) < (V_{GG} - V_{THn} - |V_{THp}|)$

$$I_{1.4} = I_B \cdot \left(1 - \frac{V_i^+ - V_i^-}{V_{GG} - V_{THn} - \left|V_{THp}\right|}\right)^2$$

$(V_i^+ - V_i^-) \geqq (V_{GG} - V_{THn} - |V_{THp}|)$ $\quad I_{1.4} = 0$

Class AB input OP amp

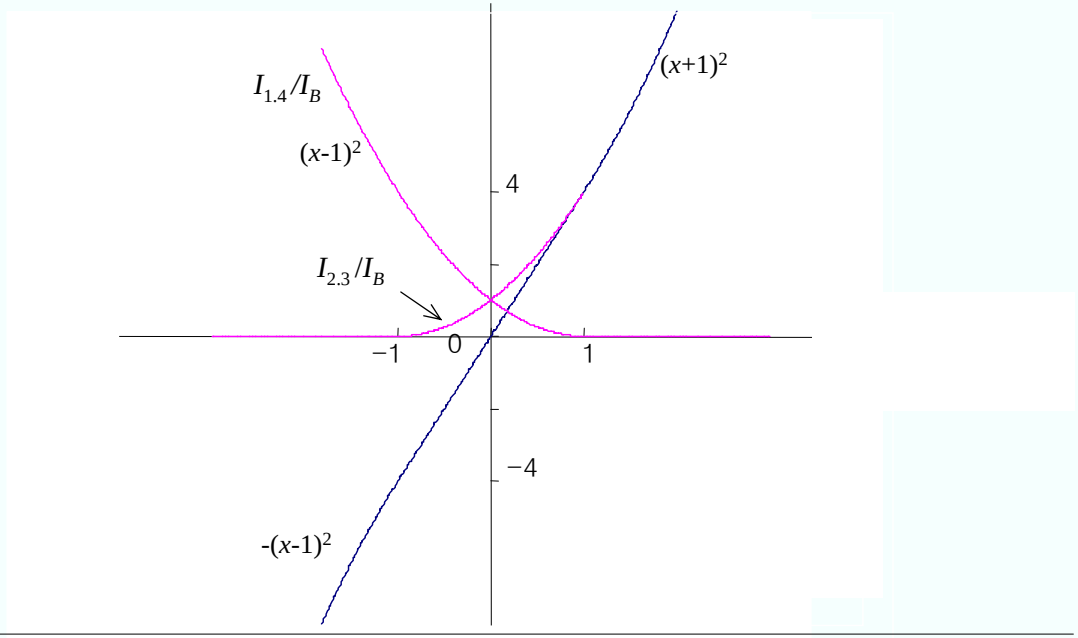


Fig 9.3.2 Output current versus differential input voltage of Class AB input OP amp

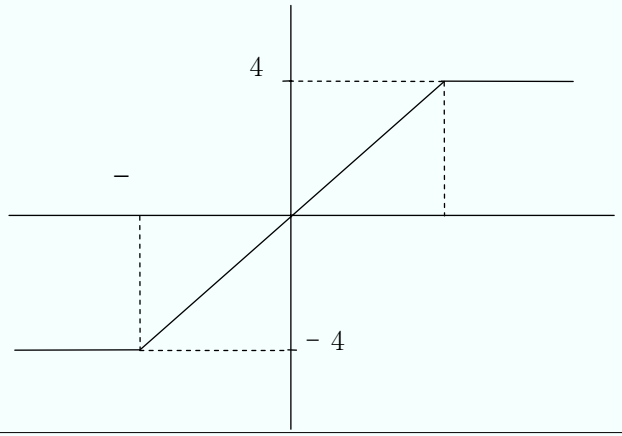
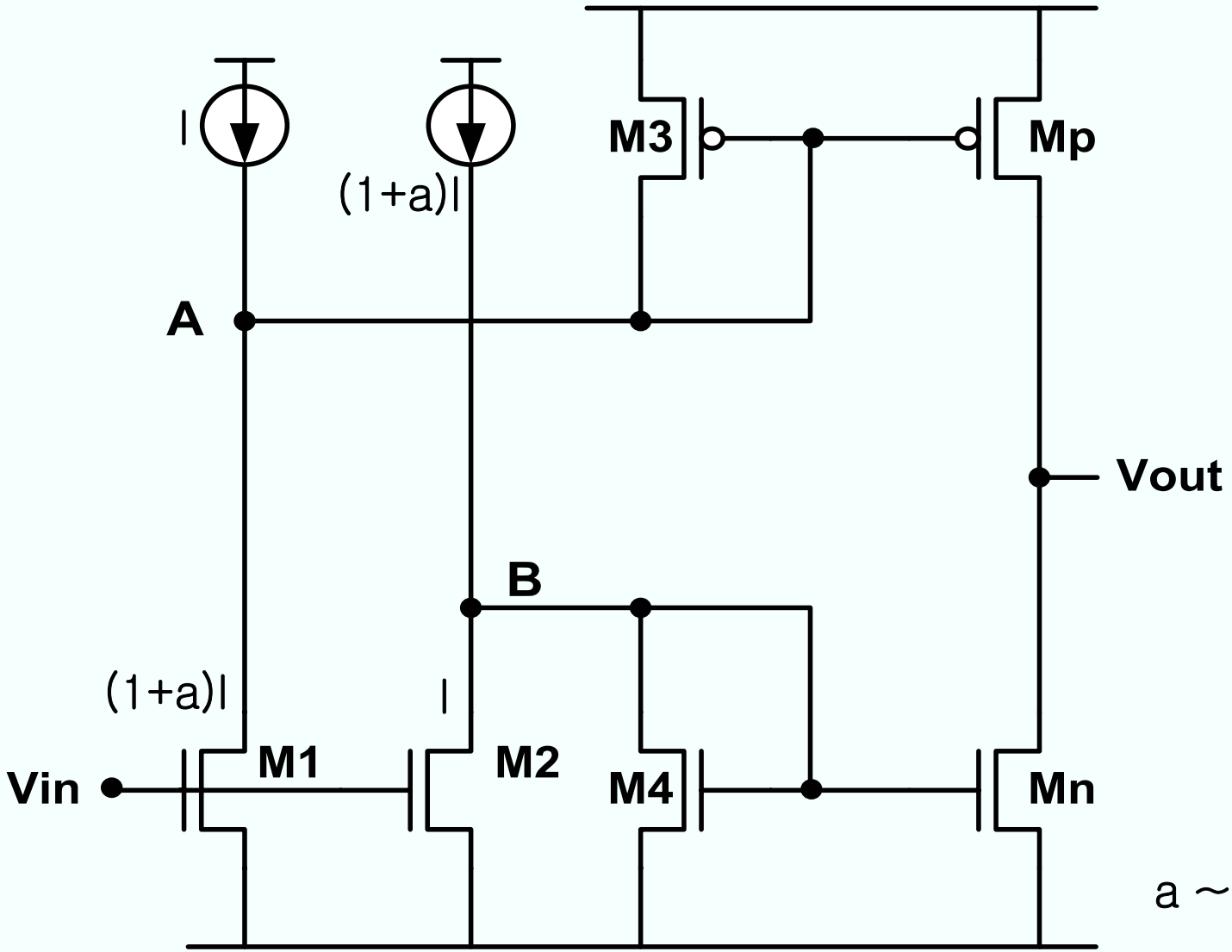


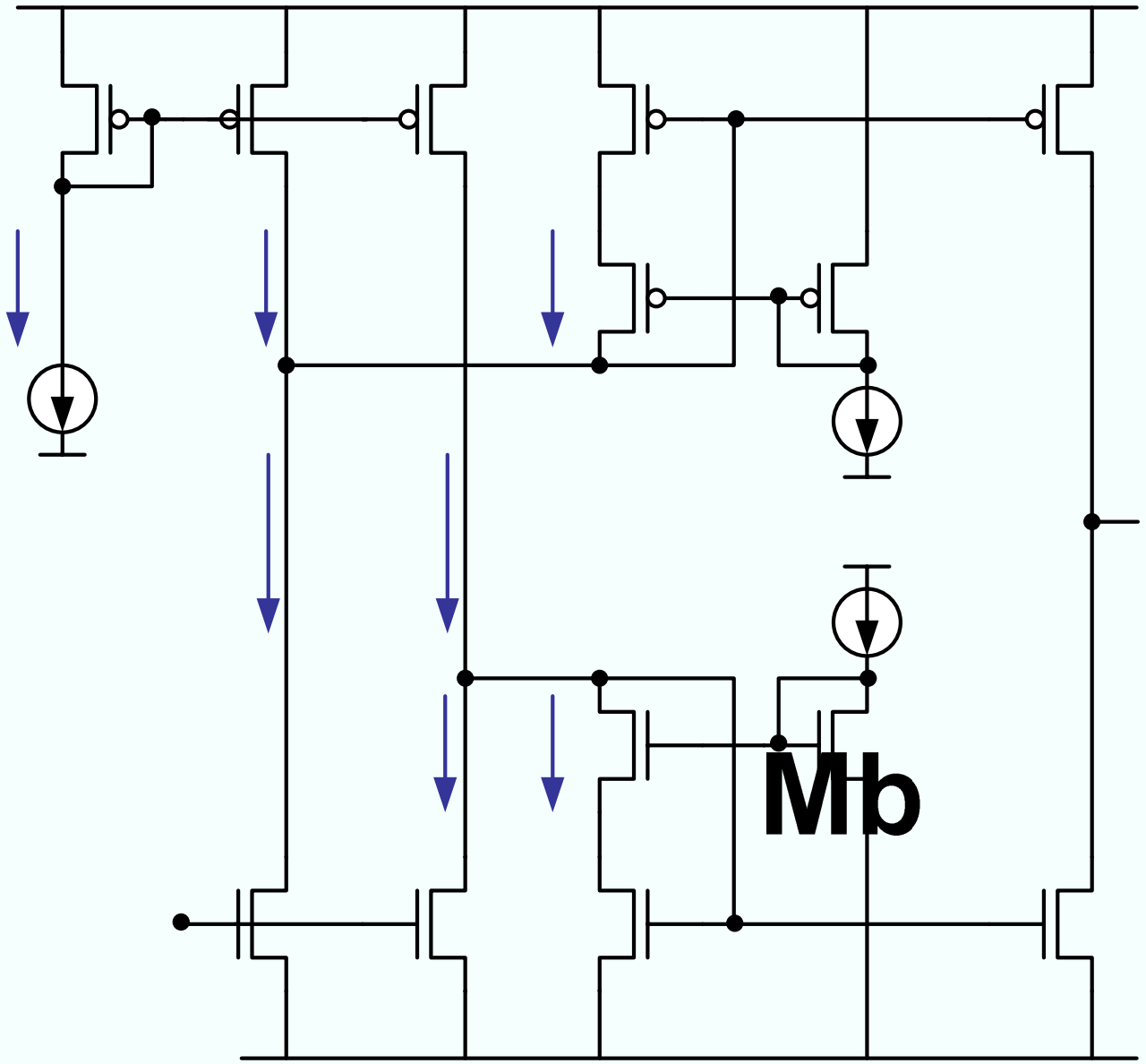
Fig 9.3.3 Output current versus differential input voltage of standard diff pair with a tail current source

Class AB output stage

Small current at small Vin, Large current for large Vin

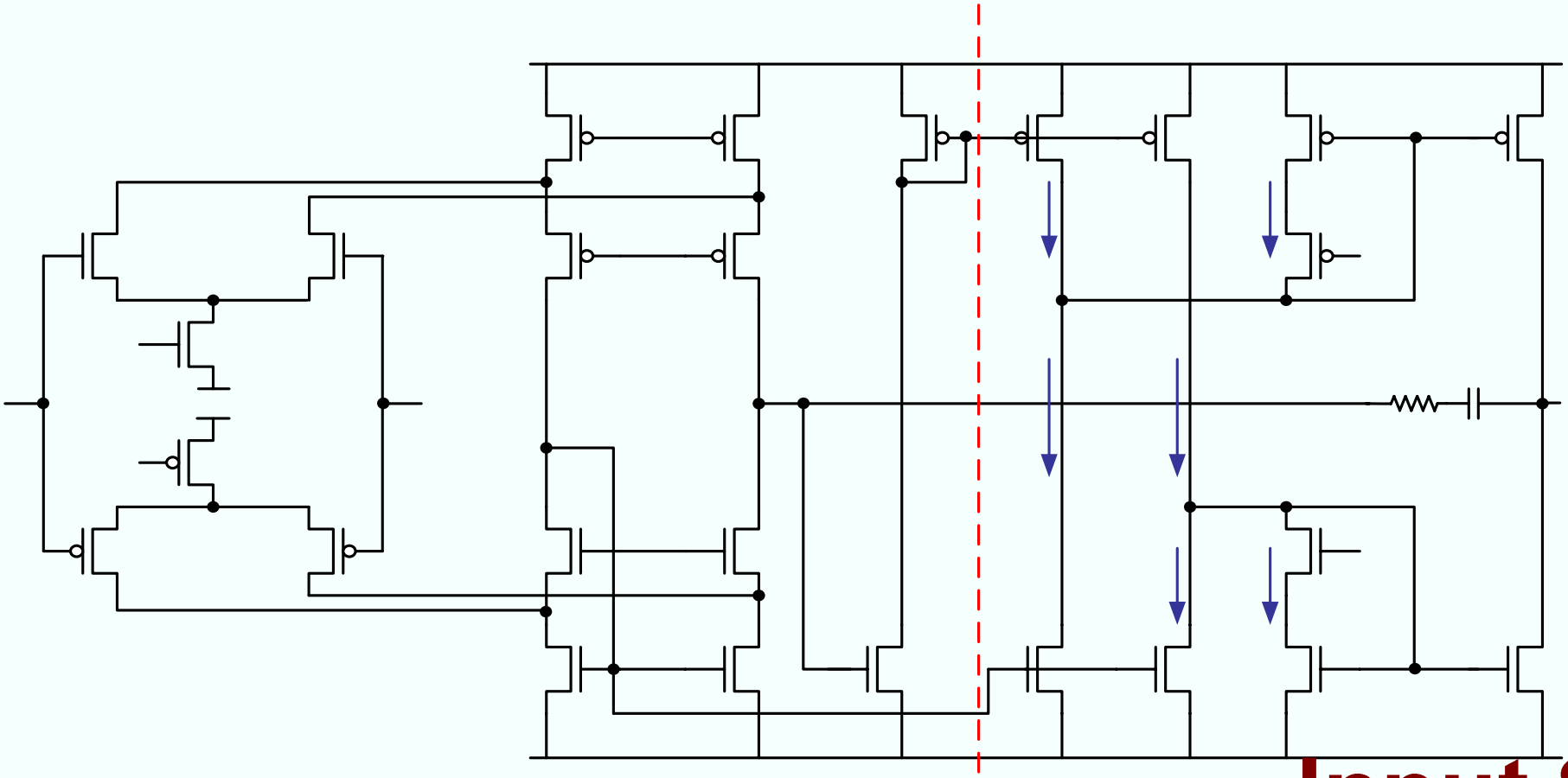


Class AB output stage



M3

Class AB OP amp



Input Stag

Current Mirror OP amp

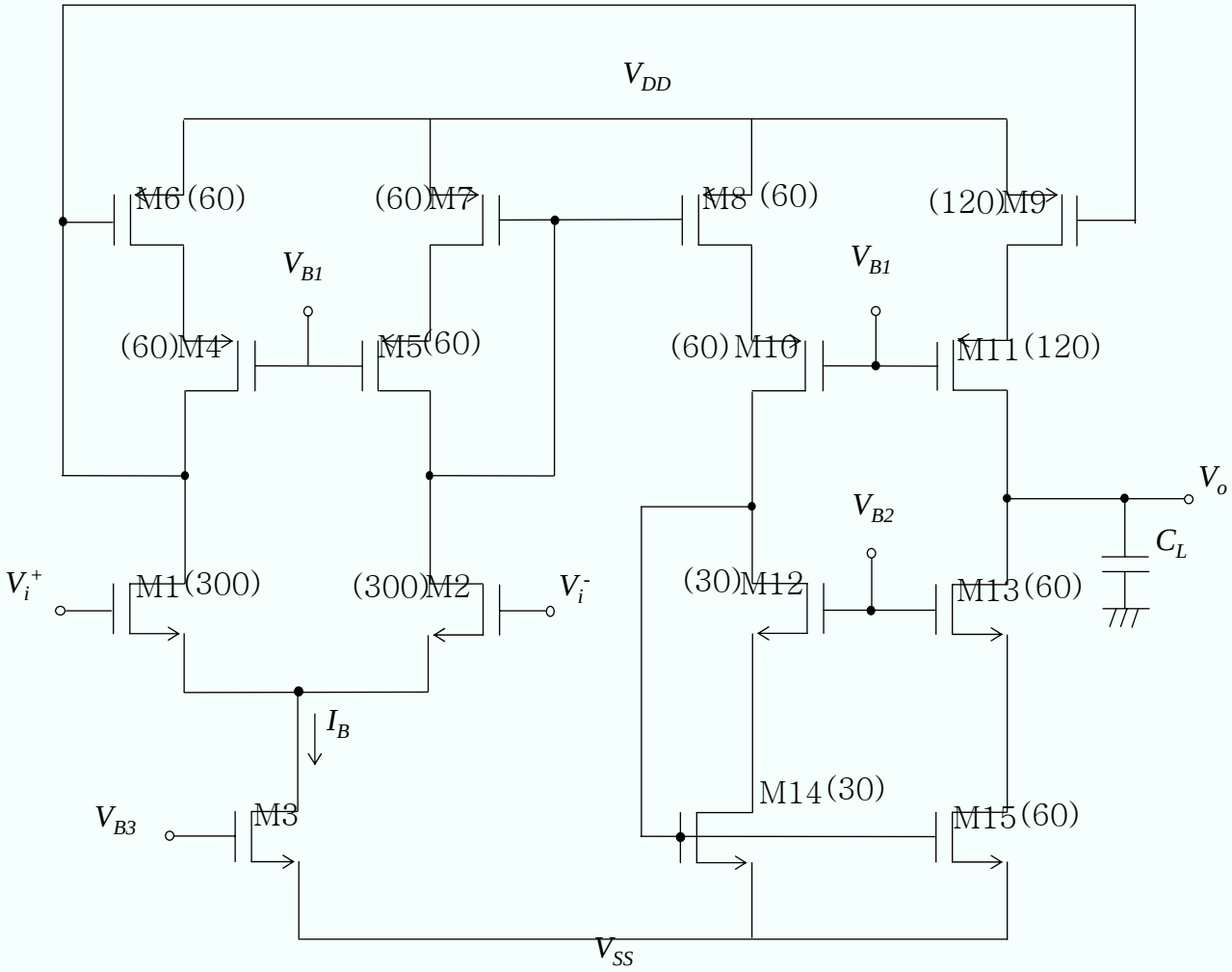
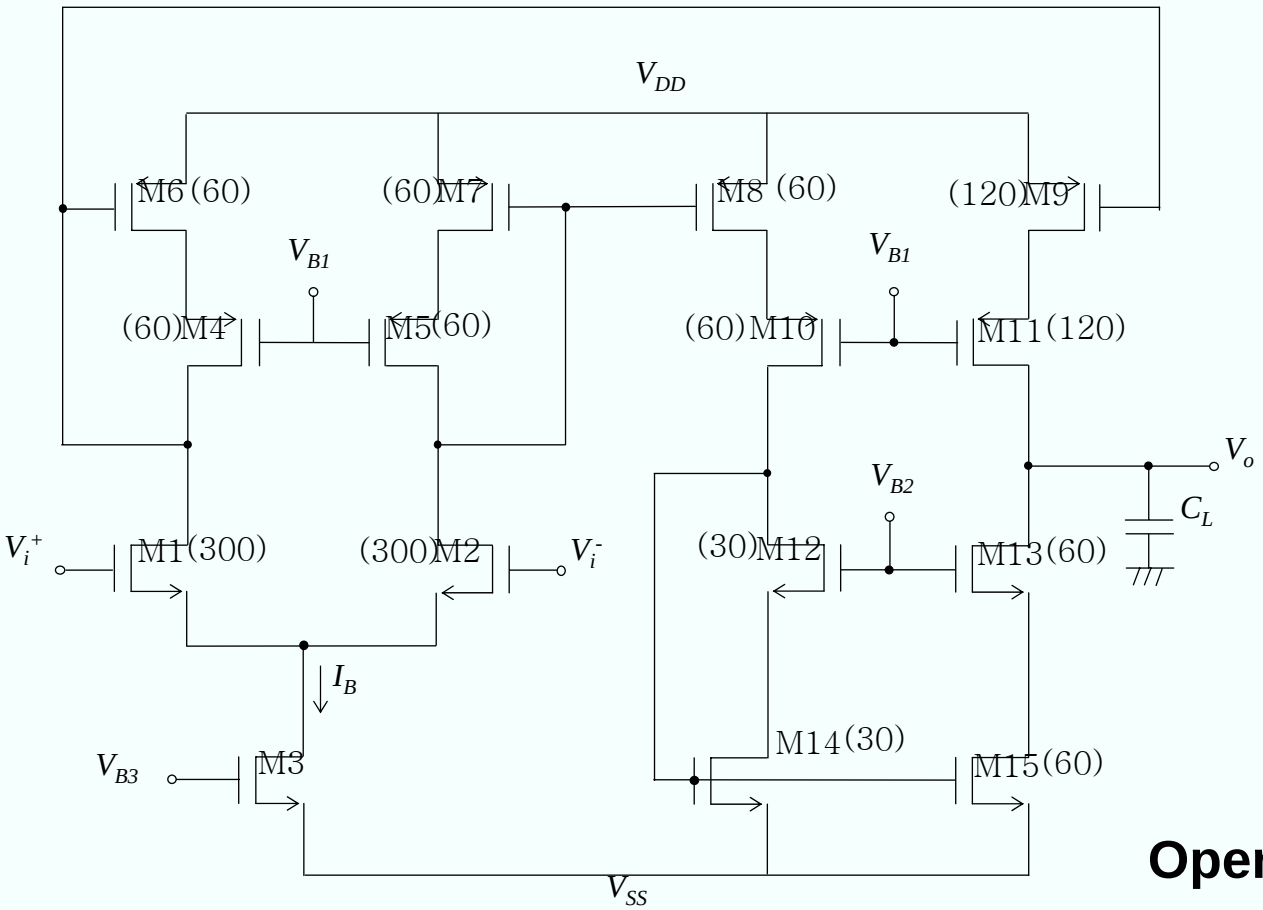


Fig 9.3.6 Current mirror OP amp

Current Mirror OP amp



$$R_o = (g_{m11}r_{o11} \cdot r_{o9}) \left\| (g_{m13}r_{o13} \cdot r_{o15}) \right.$$

$$A_{vd} = K \cdot g_{m1} \cdot R_o$$

$$A_{vd}(s) = \frac{K \cdot g_{m1} \cdot R_o}{1 + s \cdot R_o \cdot C_L}$$

$$\omega_T = \frac{K \cdot g_{m1}}{C_L}$$

$$\omega_{p2} = \frac{1}{RC} = \frac{1}{R_1C_1 + R_2C_2 + R_{10}C_{10}}$$

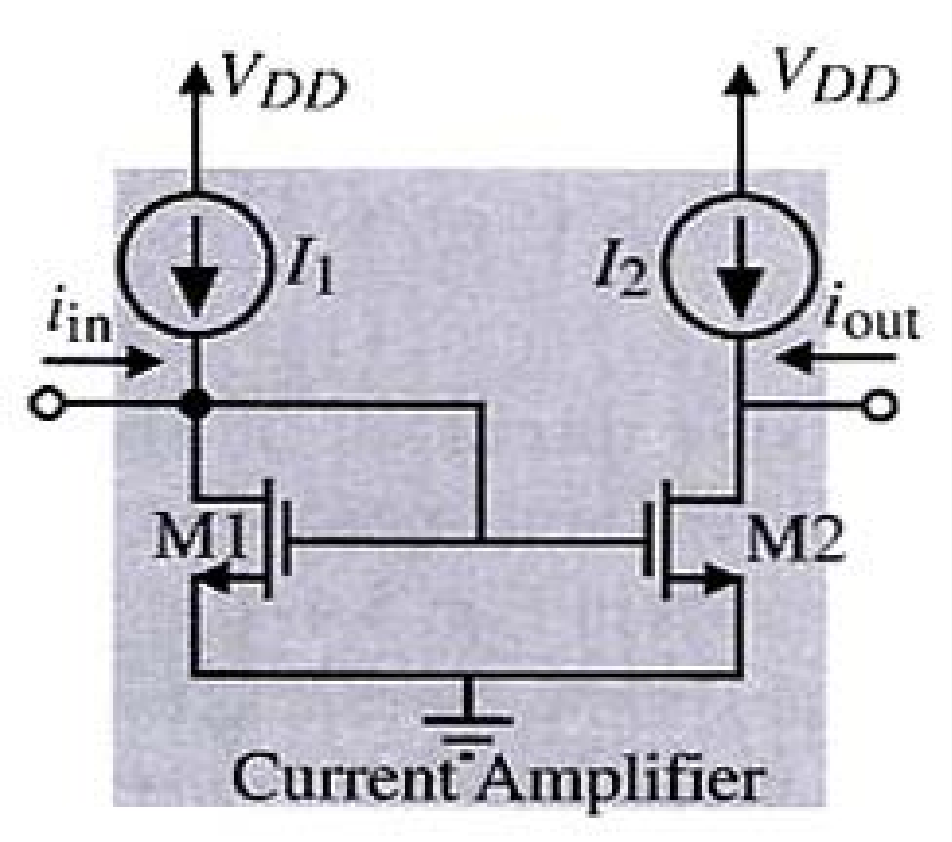
Open circuit time constant method

Large Slew rate

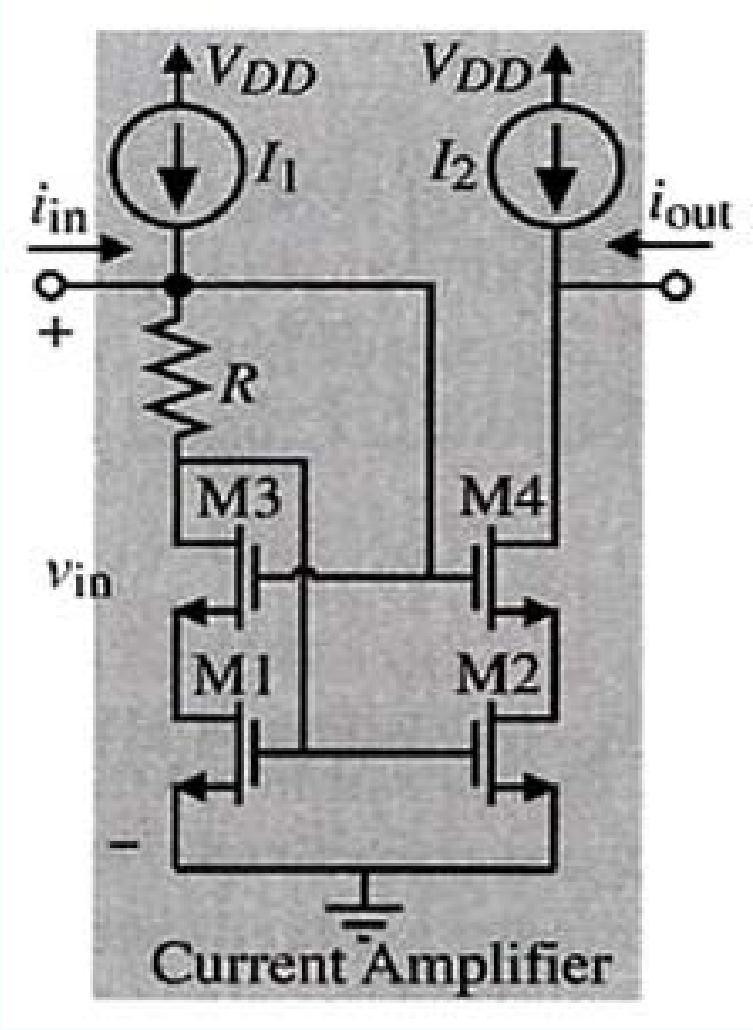
Large p2

$$SR = \frac{K \cdot I_B}{C_L}$$

Current amp

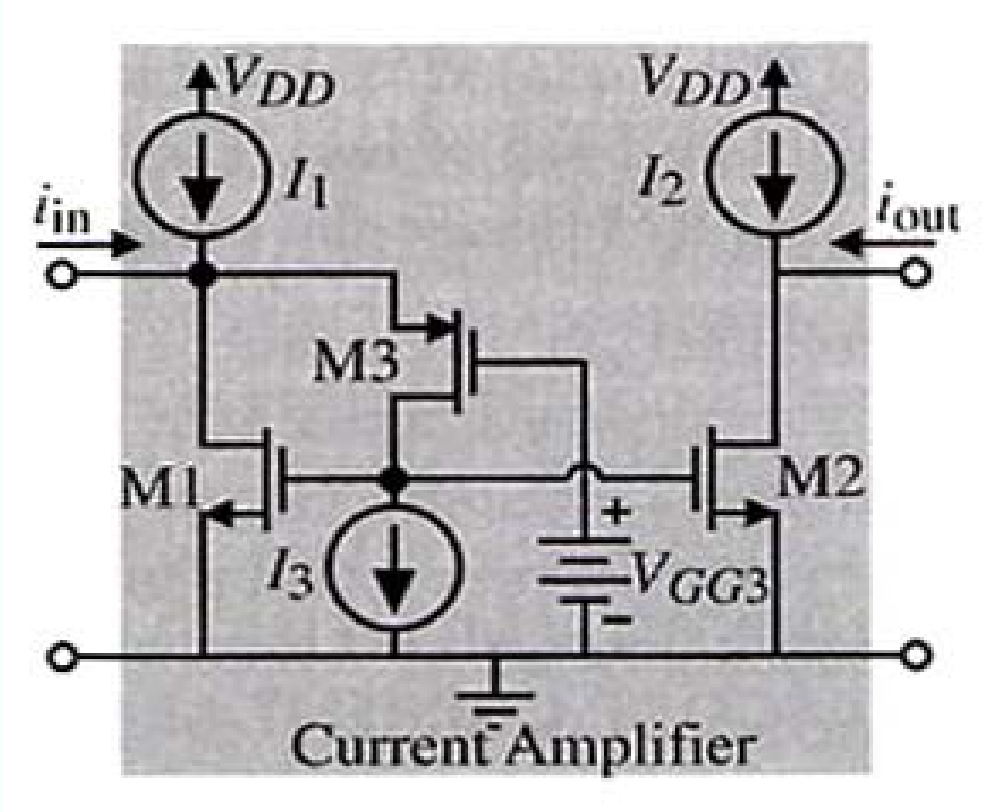


Current amp



$$R_{in} = \frac{1}{g_{m1}} + R$$

Current amp (Small Rin)



$$R_{in} = \frac{1}{g_{m1} \cdot g_{m3}\, r_{o3}}$$

Current amp (Differential)