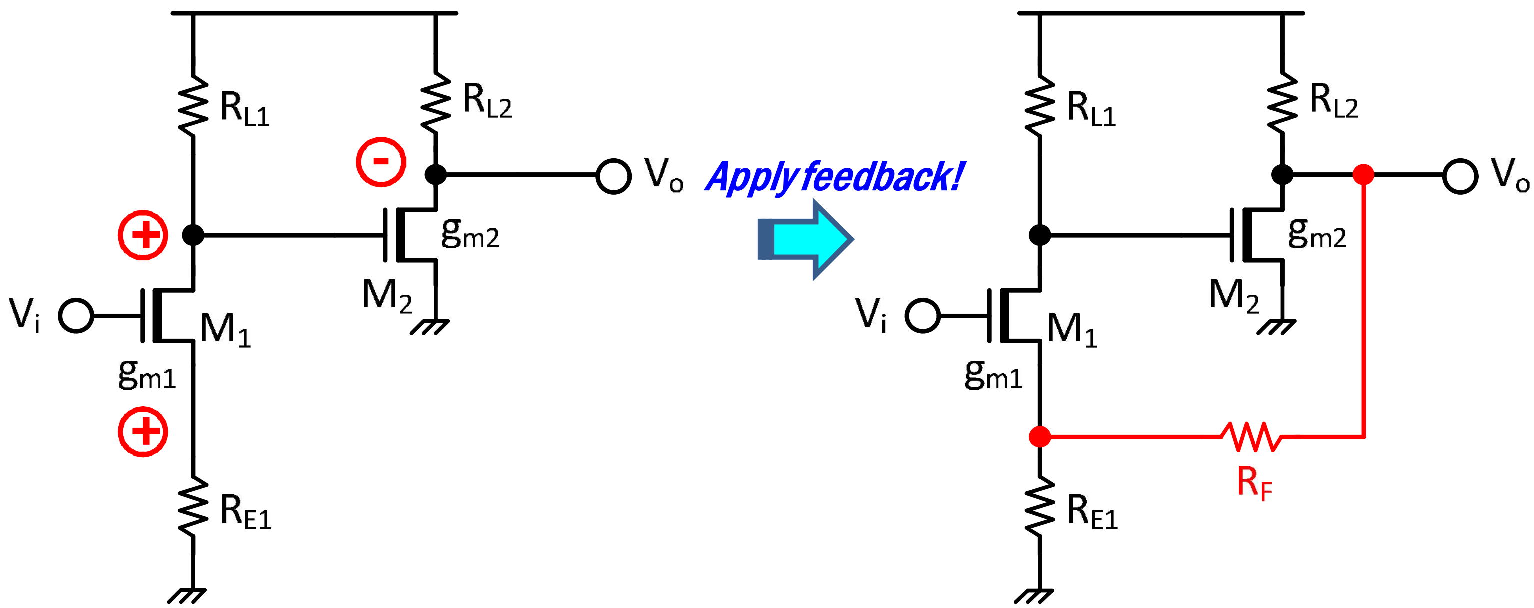
Feedback Design (1)

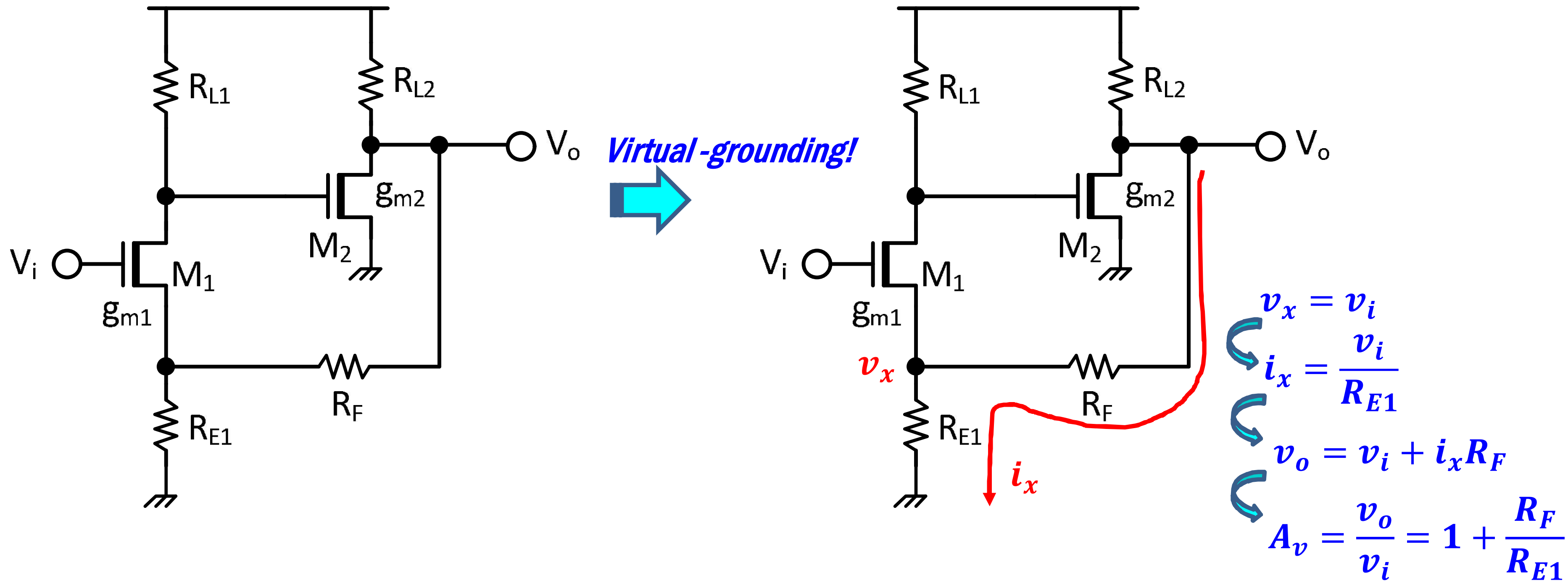
- First, it is important to identify signal phase relationship between nodes.
- Then, apply negative feedback (not positive feedback).



- In most cases, you have to make loop-gain (therefore, open-loop gain) very large (loop-gain >>1).
- This allows us to apply virtual-grounding concept for most cases of feedback designs.

Feedback Design (2)

- ❑ Using virtual-grounding, identify main signal current path.
- ❑ Calculate overall closed-loop gain factor.

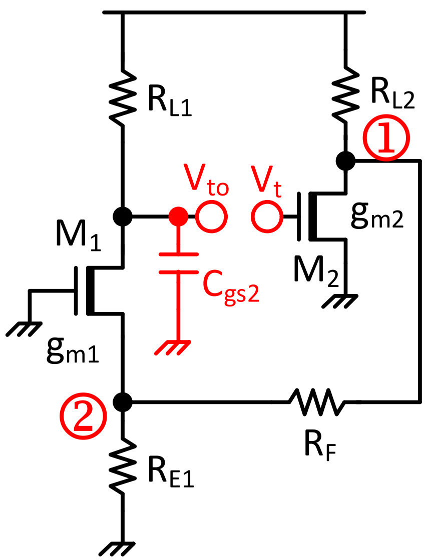


- ❑ Set the values of feedback elements (mostly, resistors) appropriately to meet a target closed-loop gain.

  ex) In this case, for 20-dB gain ⇒ $R_F/R_{E1}=9$

Feedback Design (3)

- To calculate loop-gain (=T), break the loop but include all loading effects.



$$Loop\ Gain\ (=T) = \frac{v_{to}}{v_t} = \frac{v_1}{v_t} \times \frac{v_2}{v_1} \times \frac{v_{to}}{v_2}$$

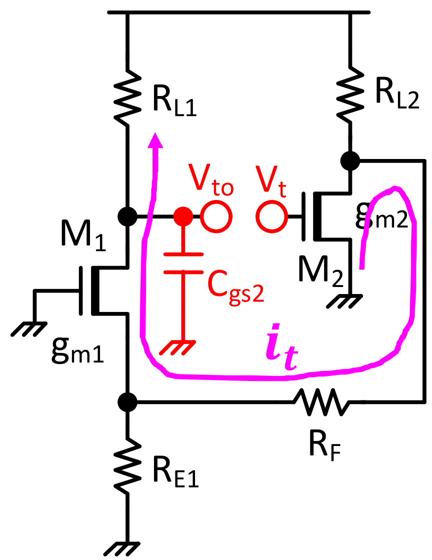
$$\frac{v_1}{v_t} = g_{m2}\left\{R_{L2} \parallel \left(R_F + R_{E1} \parallel \frac{1}{g_{m1}}\right)\right\}$$
$$\approx g_{m2}\left\{R_{L2} \parallel \left(R_F + \frac{1}{g_{m1}}\right)\right\}$$
$$\approx g_{m2}(R_{L2} \parallel R_F)$$
$$\approx g_{m2}R_F$$

$$\frac{v_2}{v_1} = \frac{R_{E1} \parallel \frac{1}{g_{m1}}}{R_F + R_{E1} \parallel \frac{1}{g_{m1}}} \approx \frac{\frac{1}{g_{m1}}}{R_F} = \frac{1}{g_{m1}R_F}$$

$$\frac{v_{to}}{v_2} = g_{m1}R_{L1}$$

$$\therefore T \approx g_{m2}R_F \times \frac{1}{g_{m1}R_F} \times g_{m1}R_{L1} = g_{m2}R_{L1}$$

Feedback Design (3)



- More intuitive approach to calculate loop-gain

1) First, identify current path in the feedback loop.

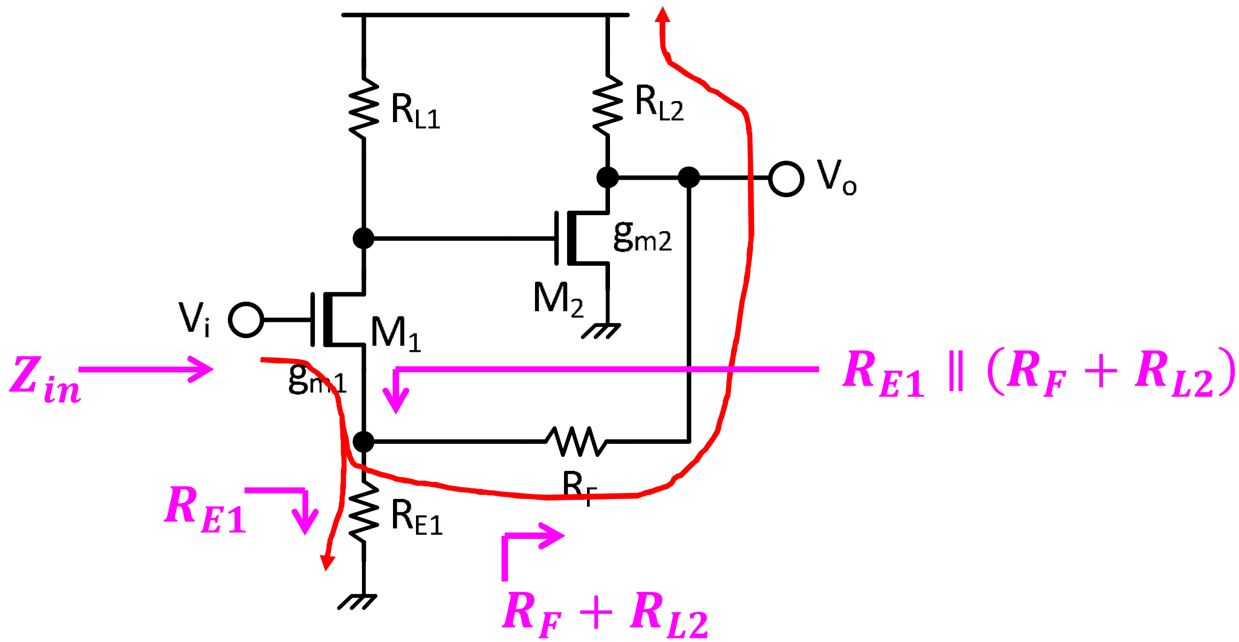
$\Rightarrow i_t = g_{m2}v_t$

2) If feedback designed properly to maximize loop-gain, then all the loop current, i_t, will be delivered to the load of M_1 and develop output voltage $v_{to} = i_t R_{L1} = g_{m2}R_{L1}v_t$.

$$\therefore \text{Loop Gain } (T) \approx g_{m2}R_{L1}$$

Feedback Design (4)

- Input impedance calculation: $Z_{inf} = Z_{in}(1 + T), \mathrm{T} = \text{loop gain}$



$$Z_{in} = \frac{1}{sC_{gs1}} + (1 + \beta)\{R_{E1} \parallel (R_F + R_{L2})\}, \beta = \frac{g_{m1}}{sC_{gs1}}$$

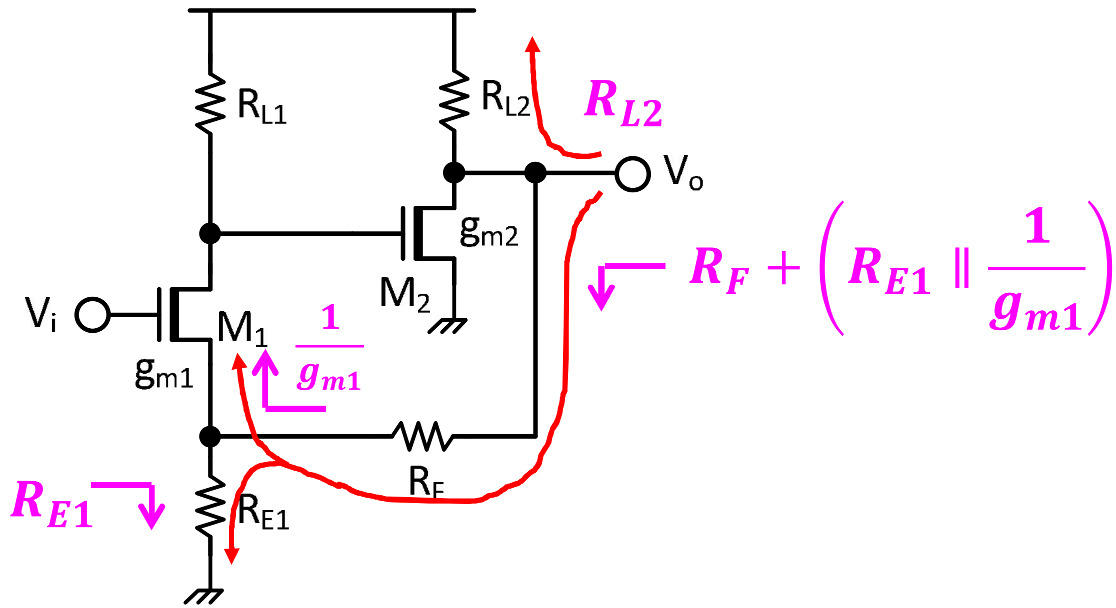
$$\approx \frac{1}{sC_{gs1}} + \beta R_{E1} = \frac{1 + g_{m1}R_{E1}}{sC_{gs1}}$$

Note: input capacitance will be decreased further due to feedback.

$$\therefore Z_{inf} = Z_{in}(1 + T) = \frac{(1 + g_{m1}R_{E1})(1 + g_{m2}R_{L1})}{sC_{gs1}}$$

Feedback Design (5)

- Output impedance calculation: $Z_{outf} = \frac{Z_{out}}{1+T}$, T = loop gain

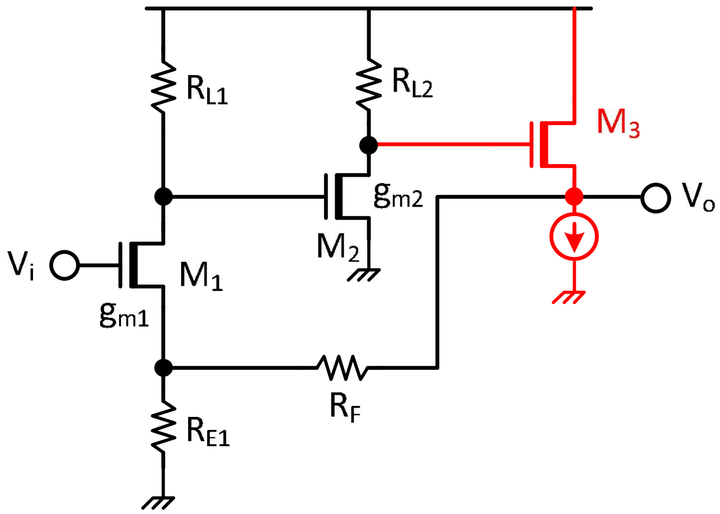


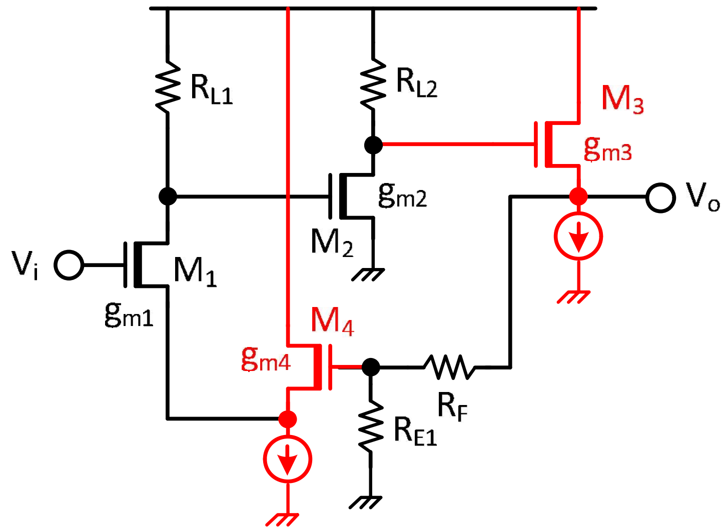
$$Z_{out} = R_{L2} \parallel \left\{R_F + \left(R_{E1} \parallel \frac{1}{g_{m1}}\right)\right\}$$

$$\approx R_F + \left(R_{E1} \parallel \frac{1}{g_{m1}}\right) \approx R_F + \frac{1}{g_{m1}} \approx R_F$$

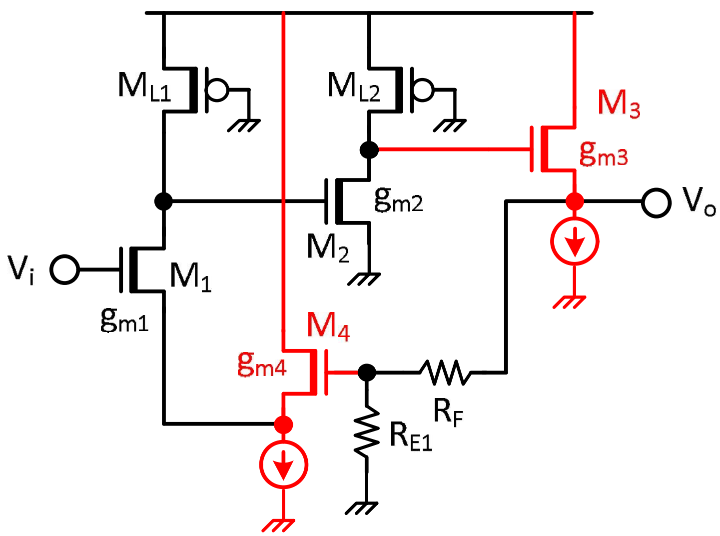
$$\therefore Z_{outf} = \frac{Z_{out}}{1+T} = \frac{R_F}{1+g_{m2}R_{L1}}$$

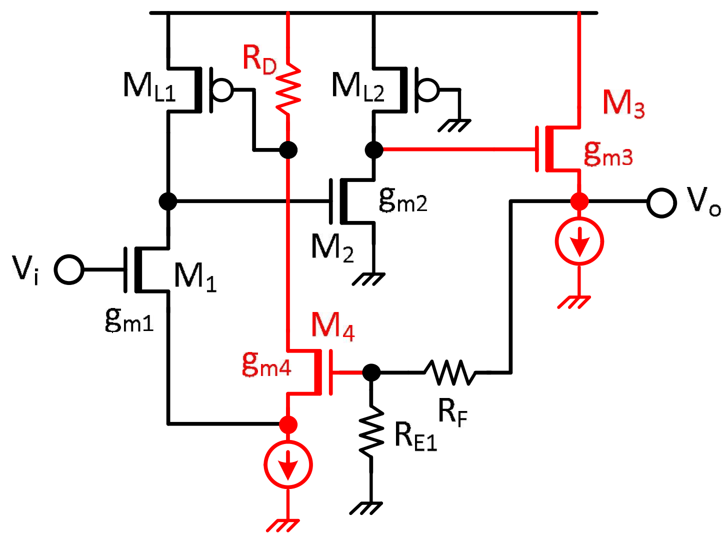
Feedback Design (6)



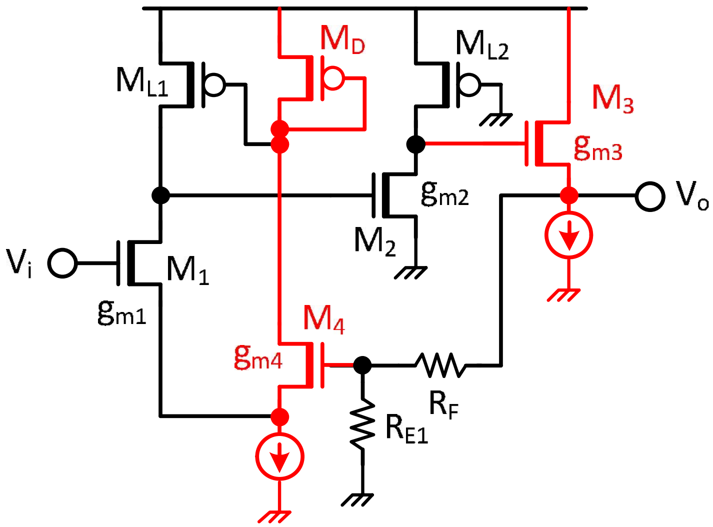


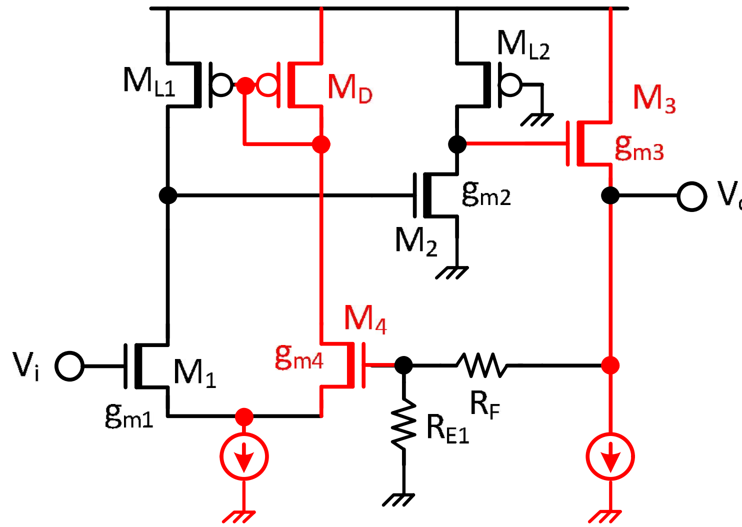
Feedback Design (7)



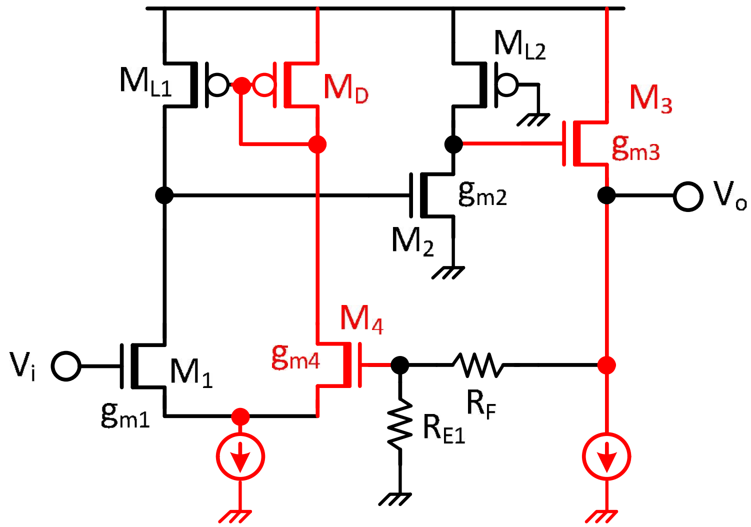


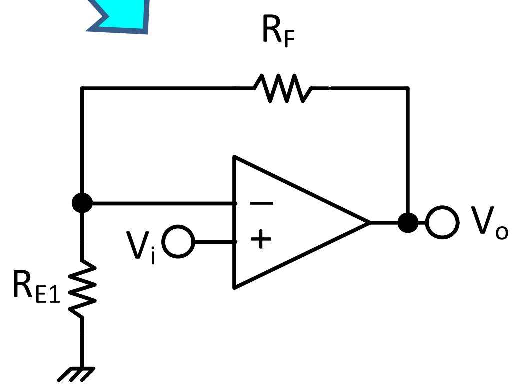
Feedback Design (8)

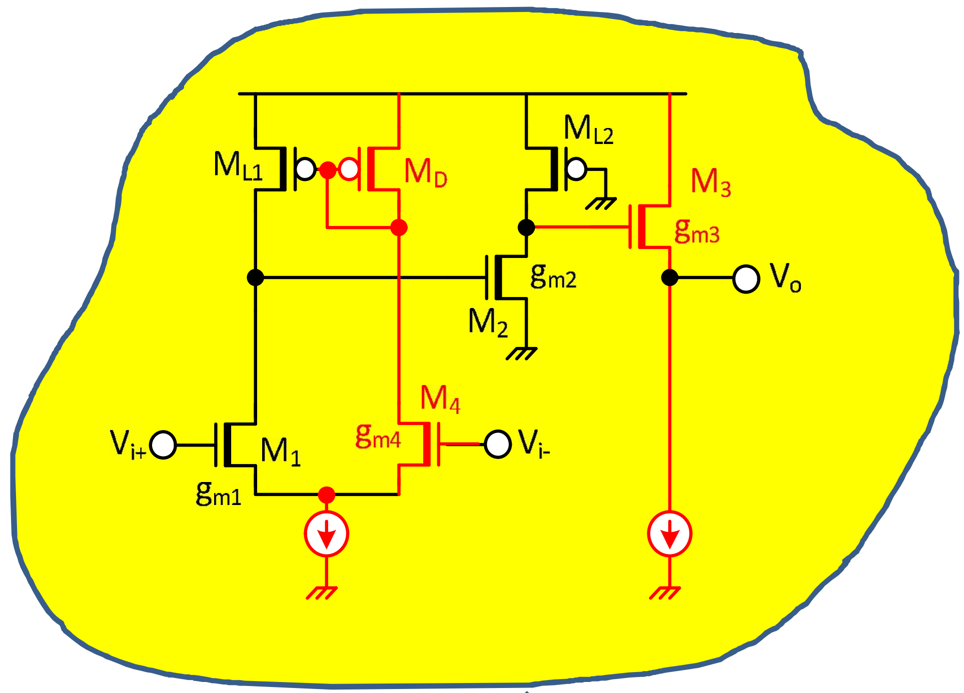


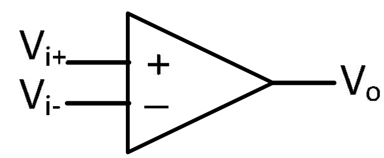


Feedback Design (9)

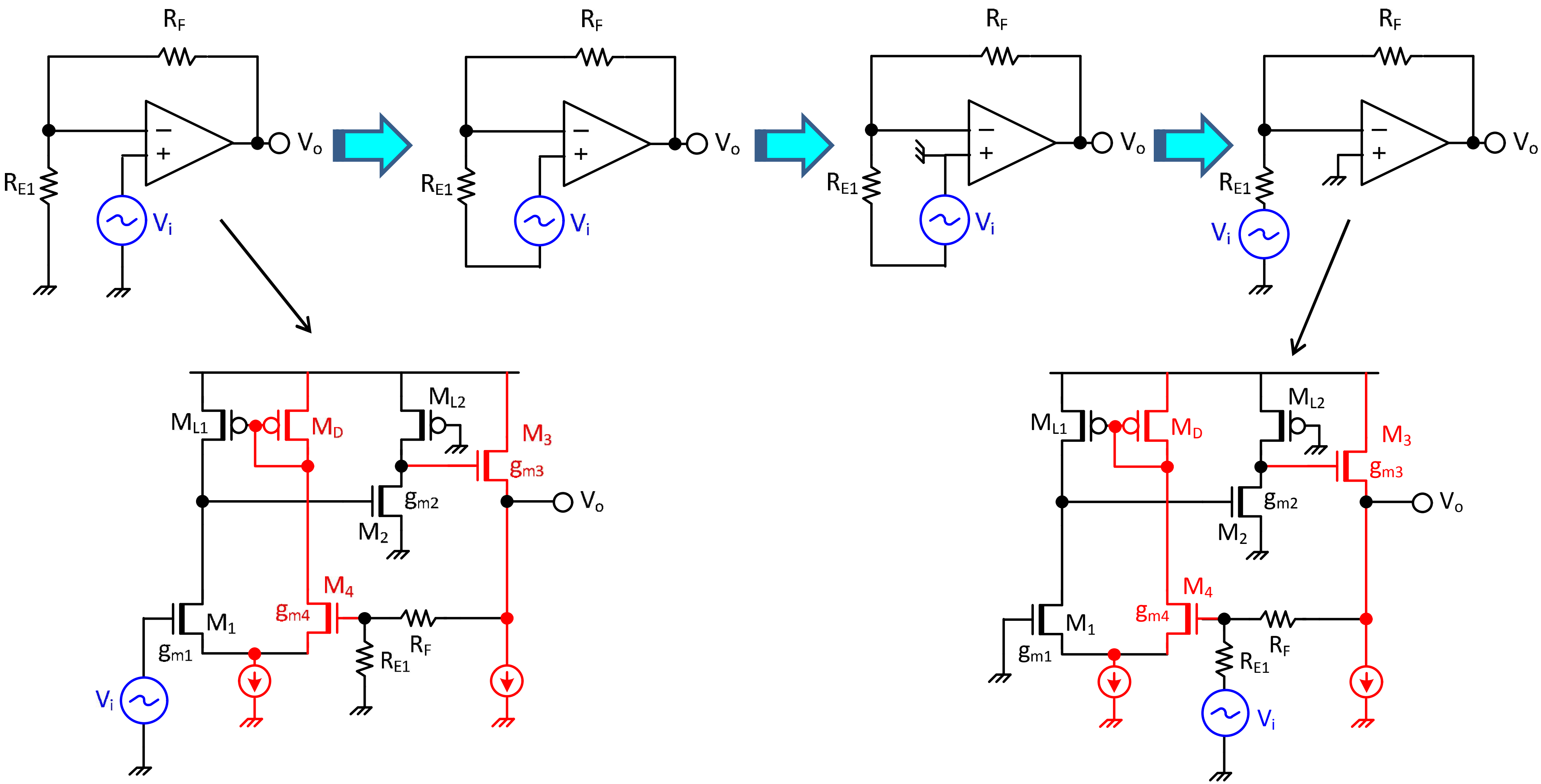








Feedback Design (10)



Feedback Design (11)