Lecture
Active-Load Differential Amplifiers

Vincent Chang

Outline

BJT

- Analysis-by-inspection
- Norton equivalent

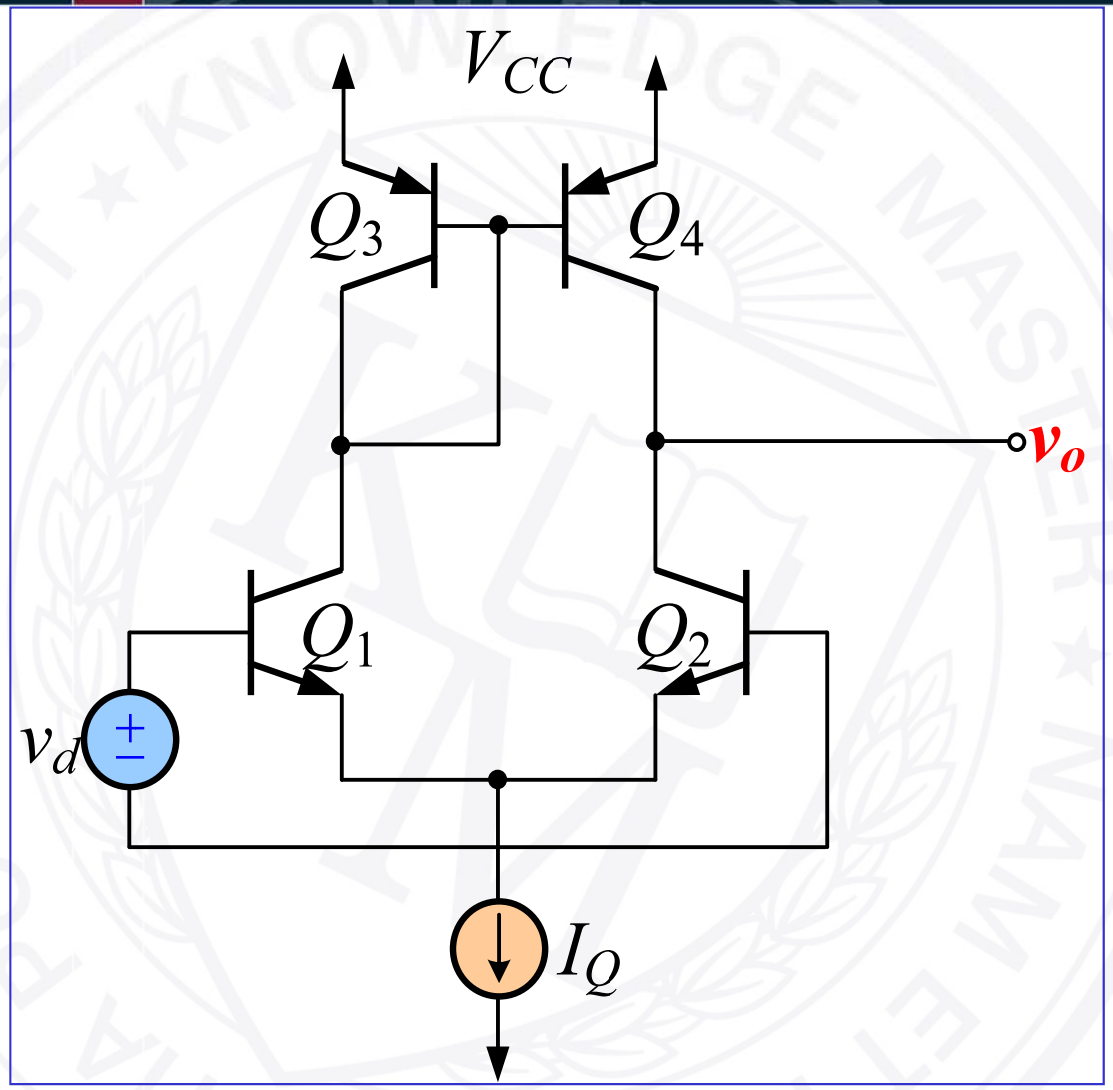
CMOS

- BJT vs. CMOS
- Norton equivalent
- Gain

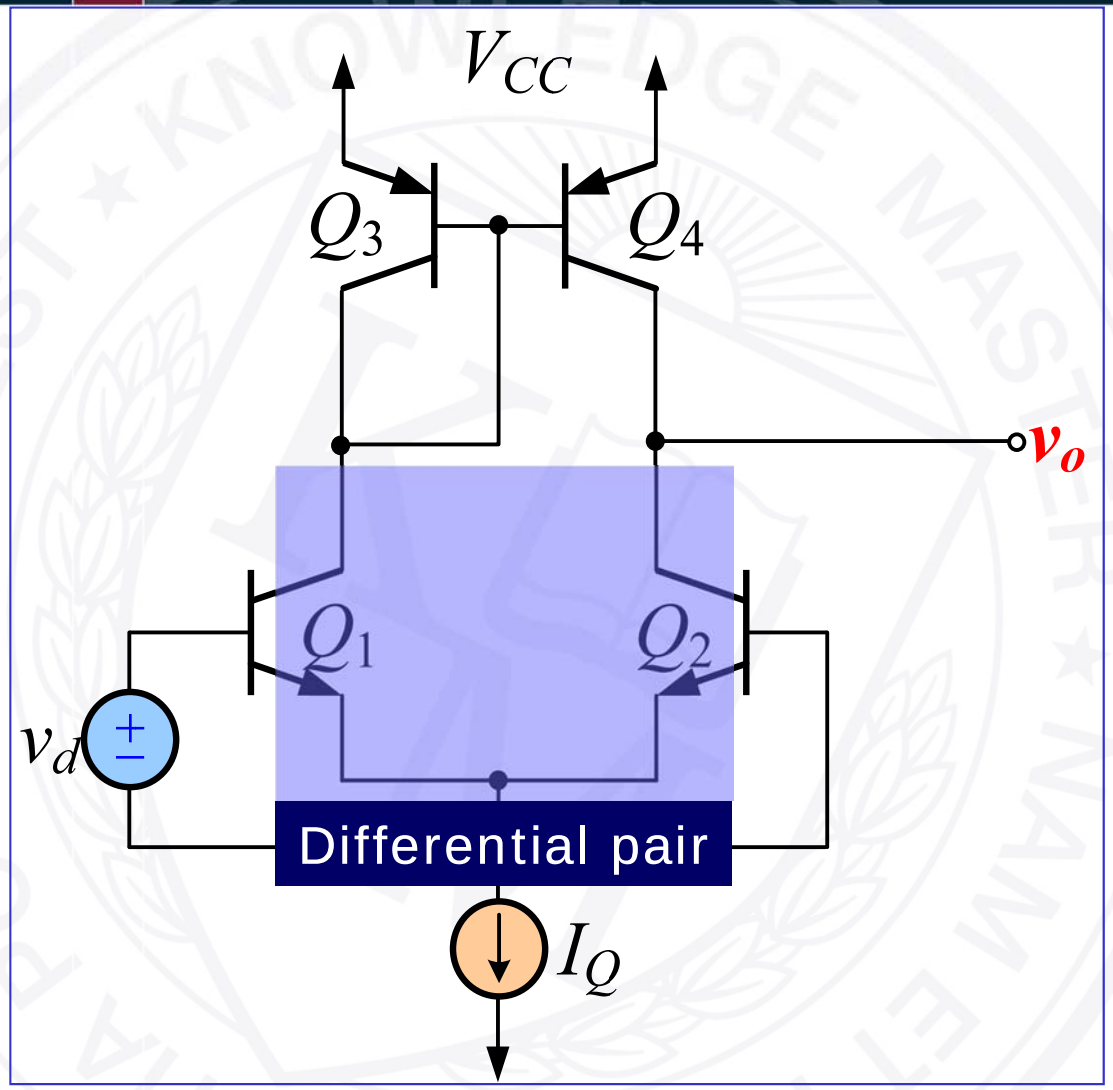
Output resistance

- Question
- Derivation

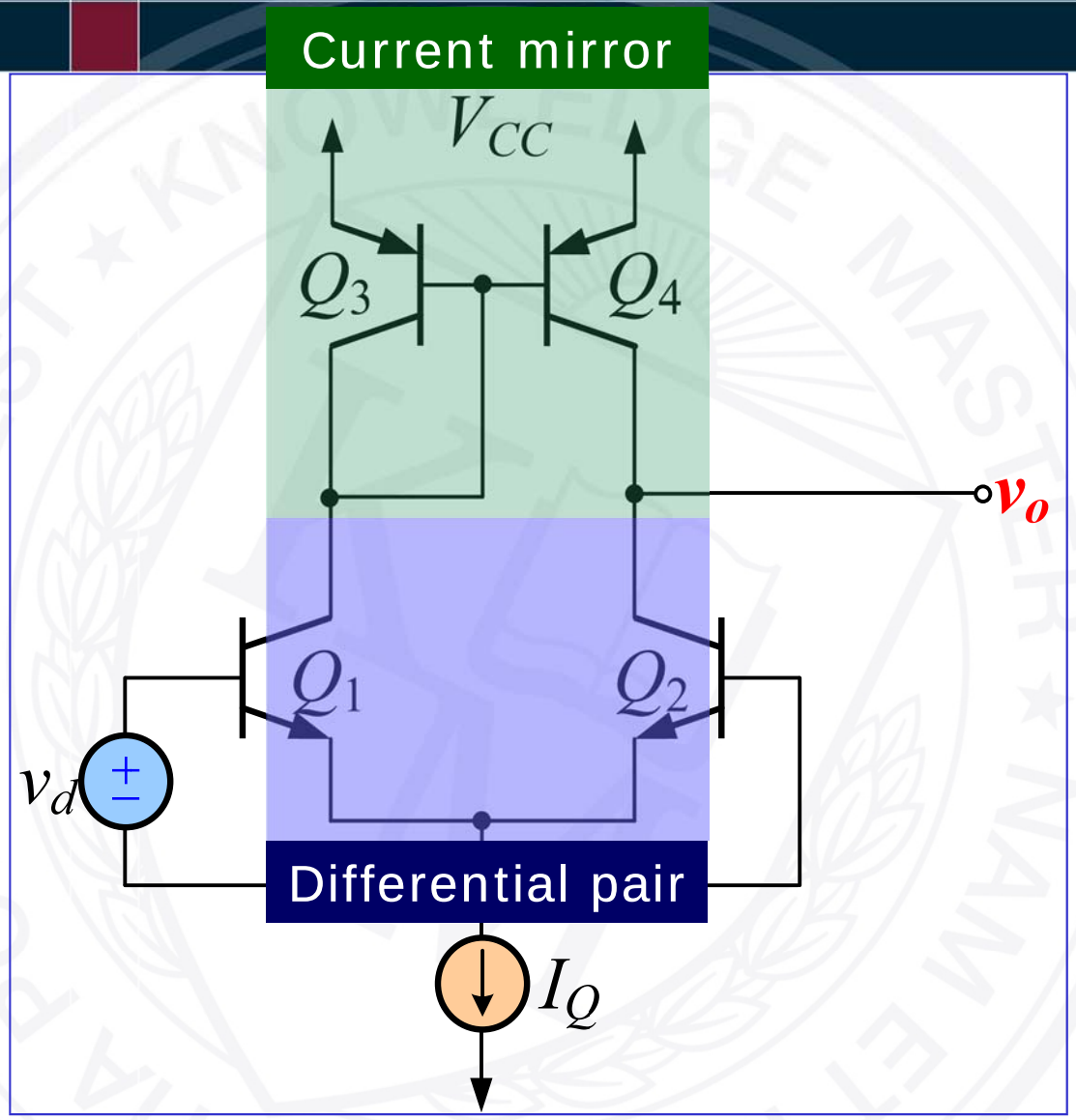
Active-Load D-Amp



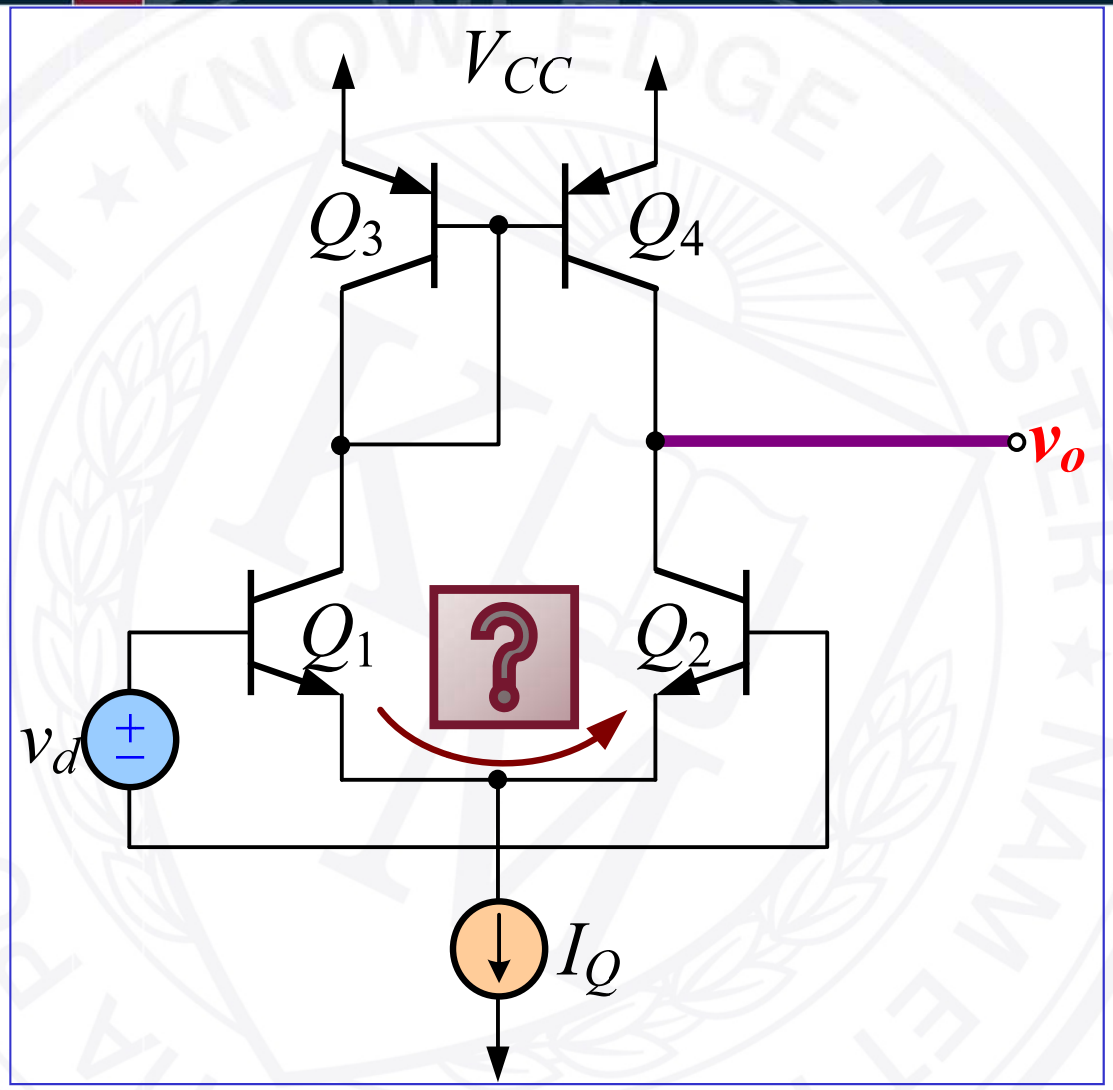
Active-Load Differential Amplifier



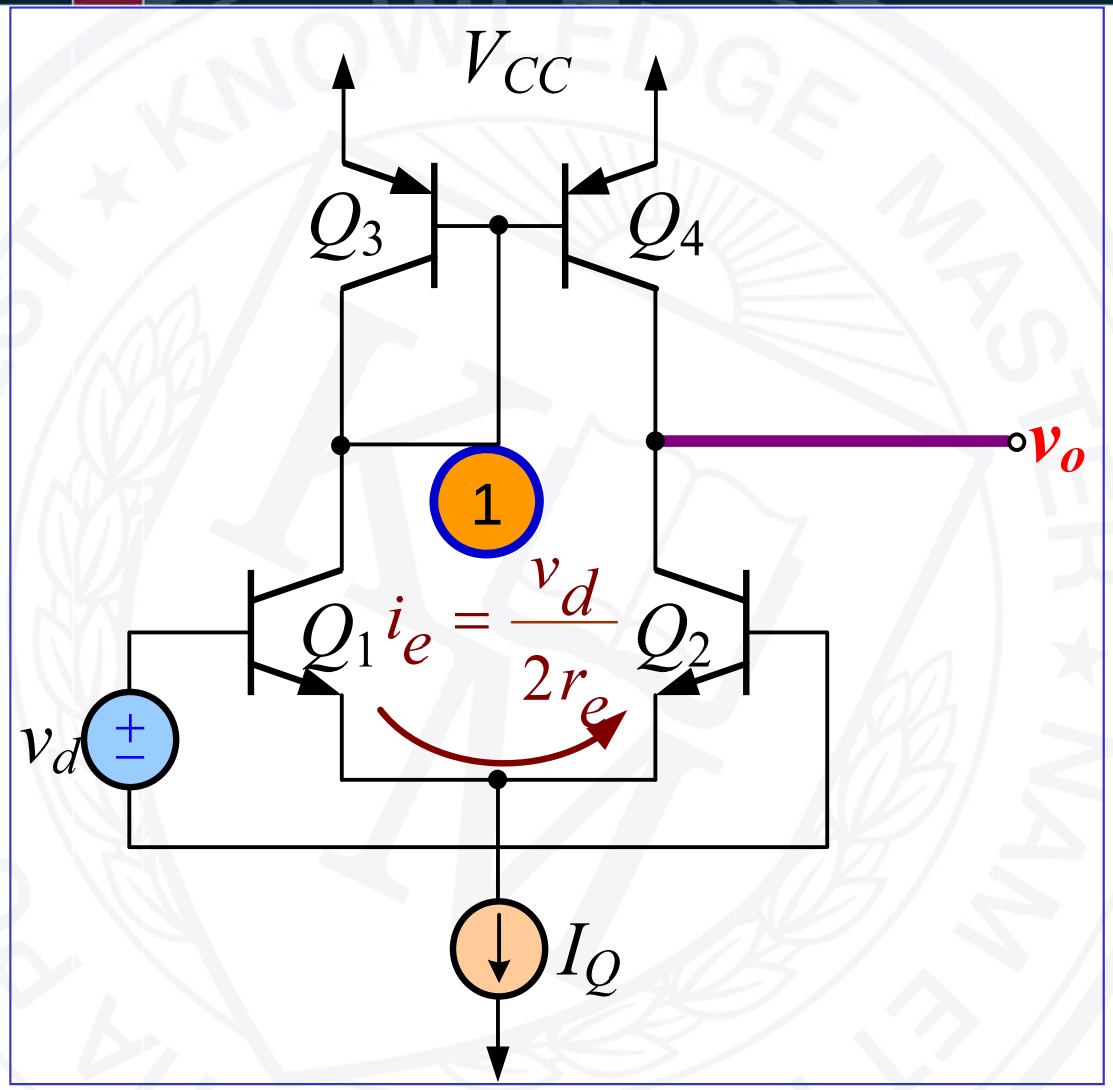
Active-Load Differential Amplifier



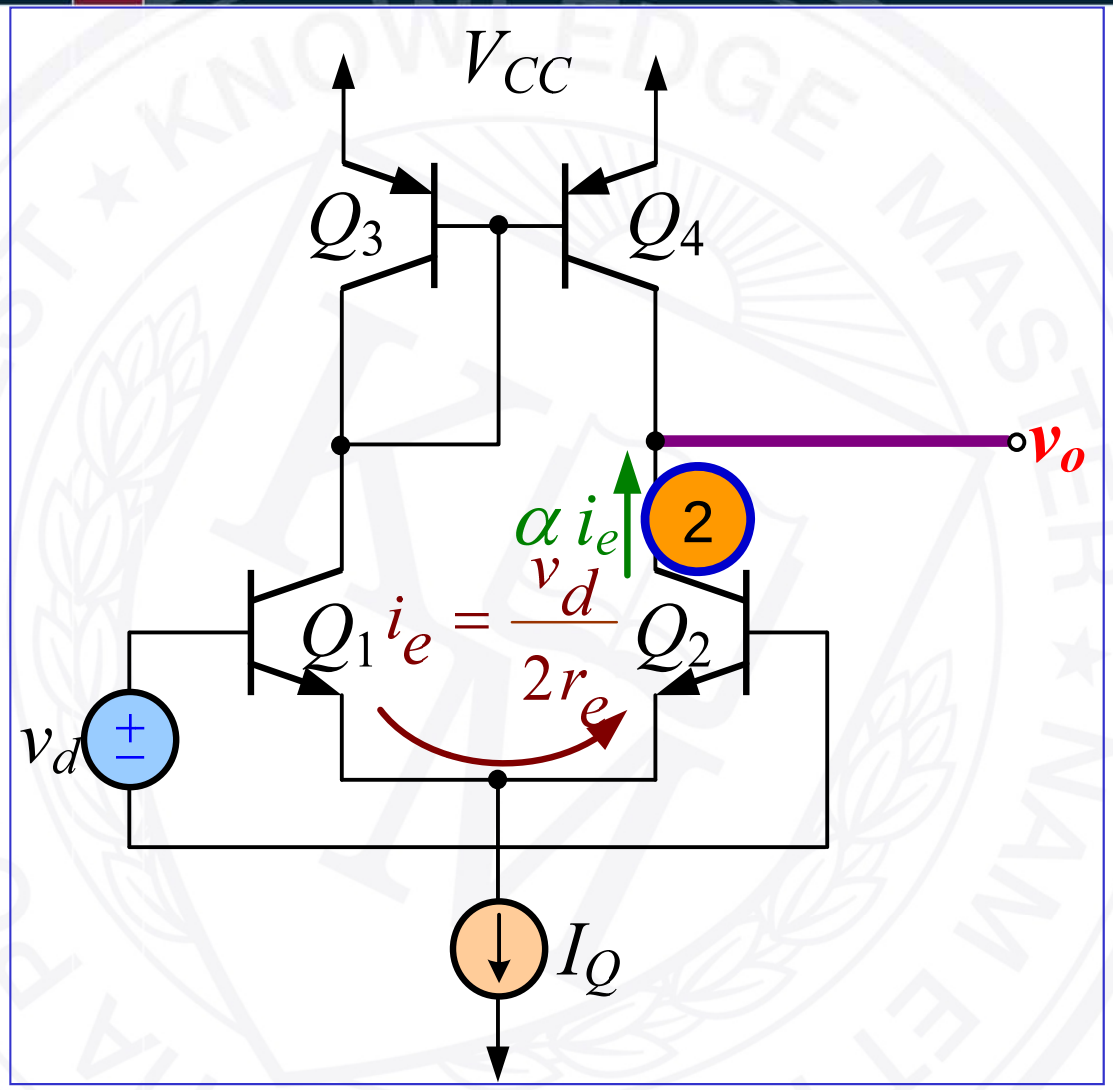
Analysis-by-Inspection



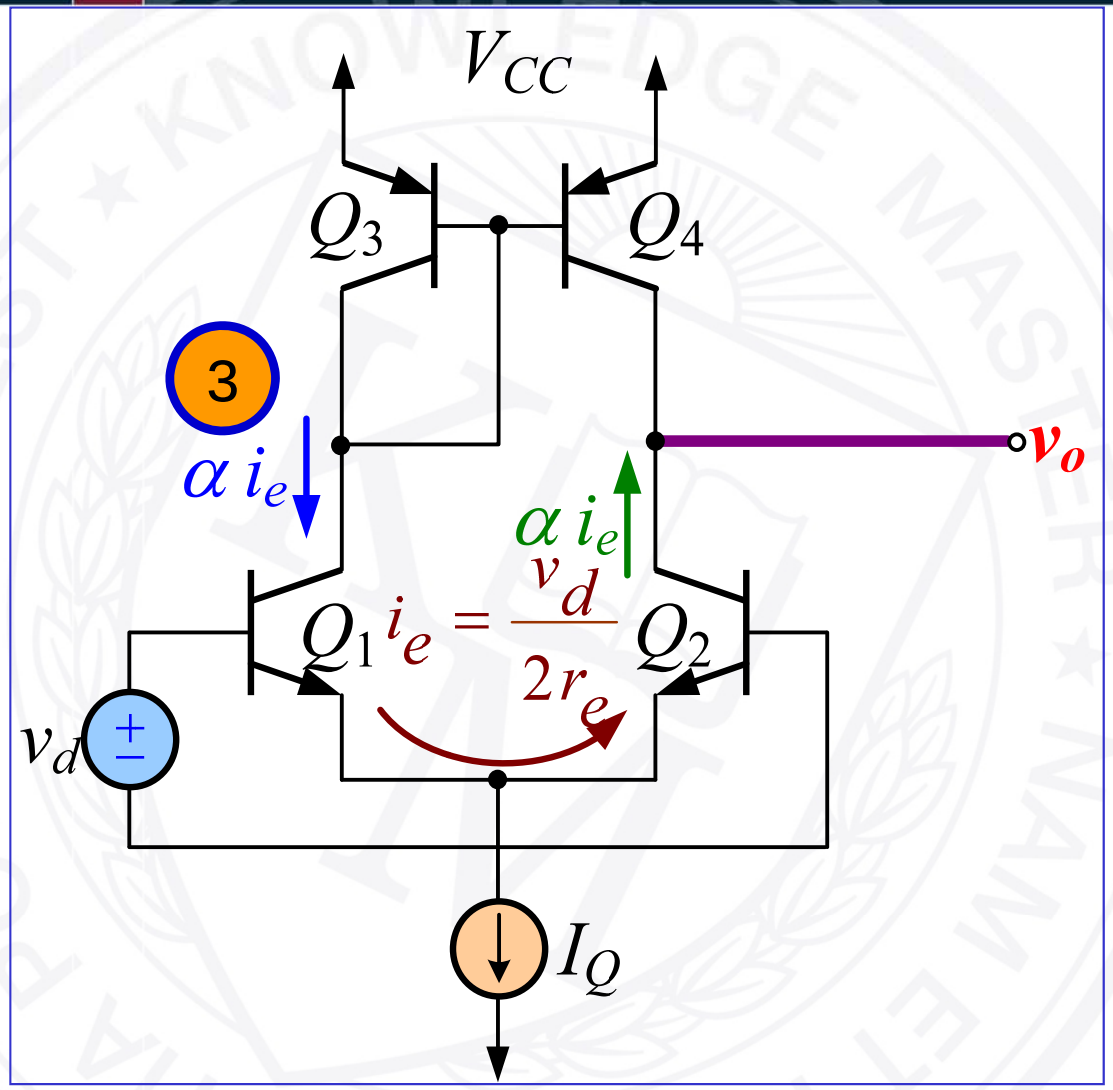
Analysis-by-Inspection (Take Note)



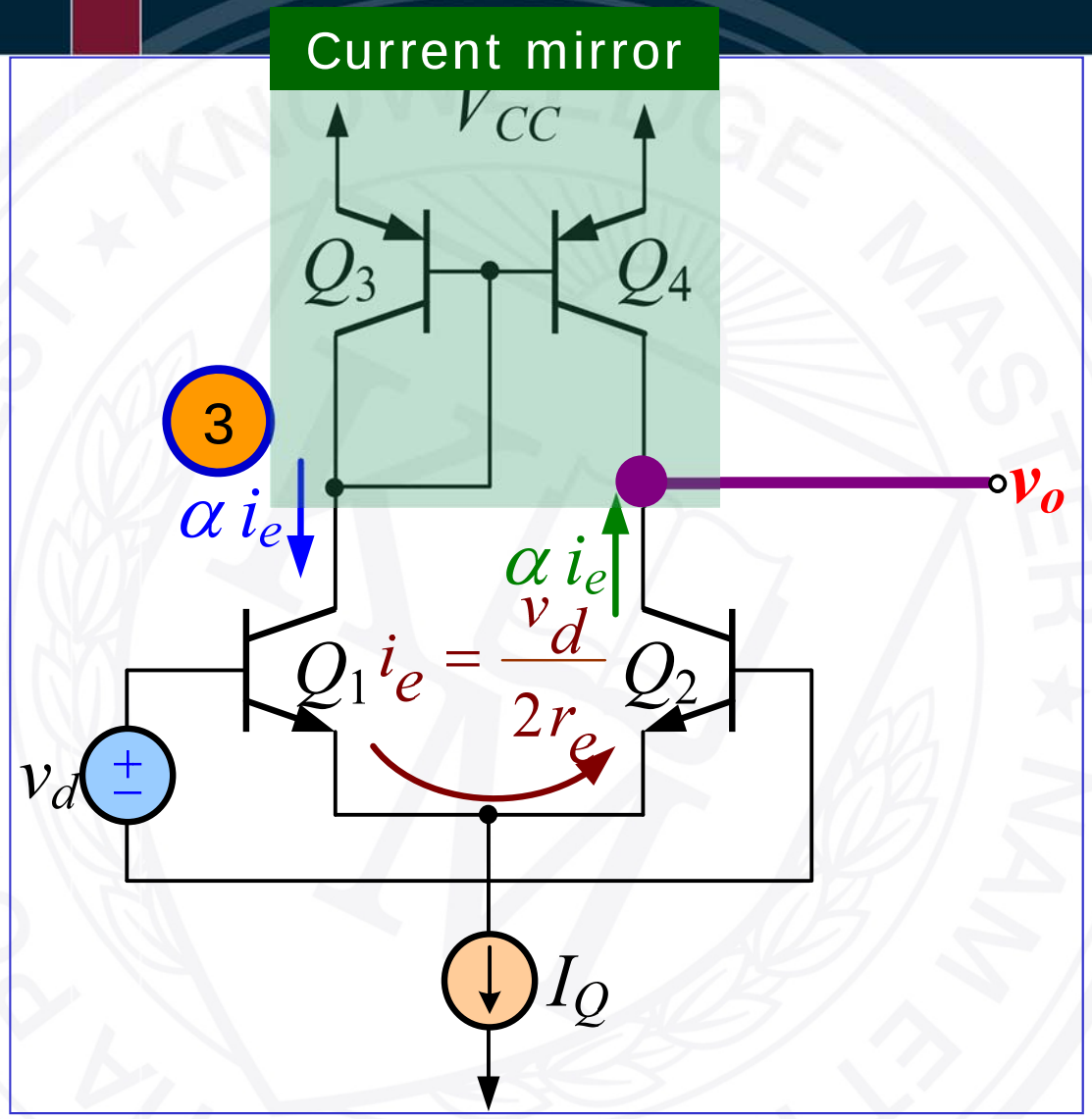
Analysis-by-Inspection



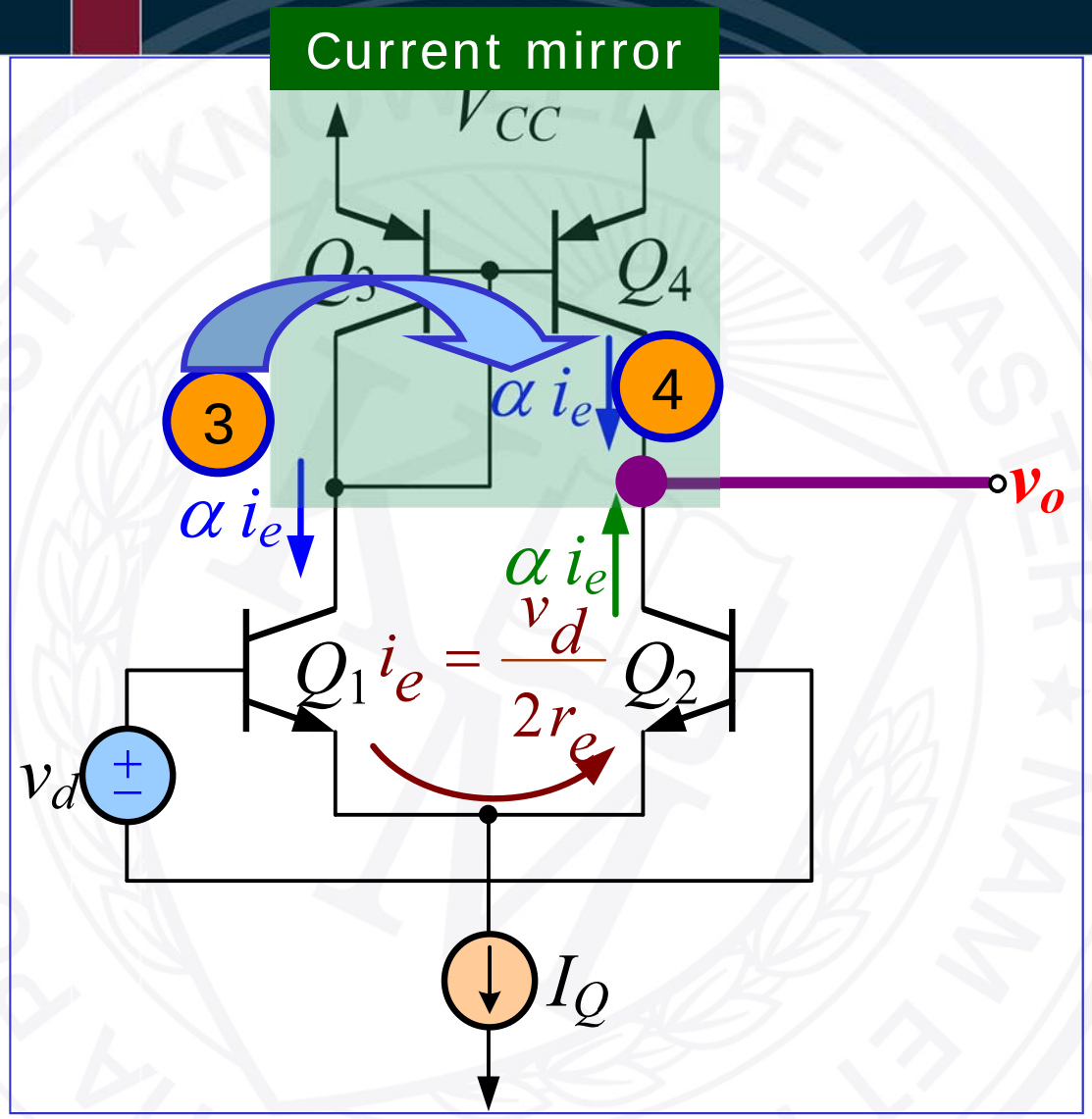
Analysis-by-Inspection



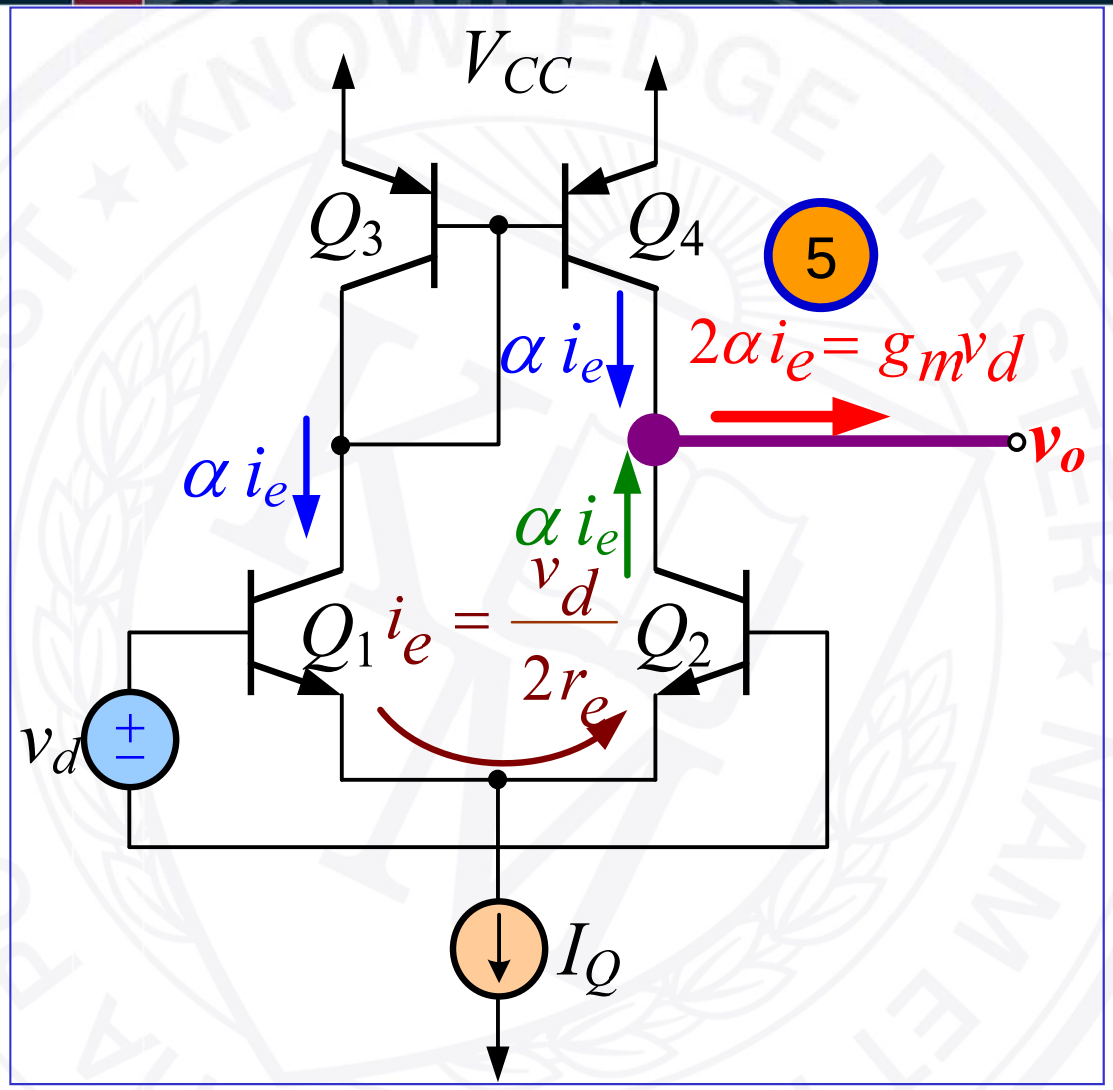
Analysis-by-Inspection



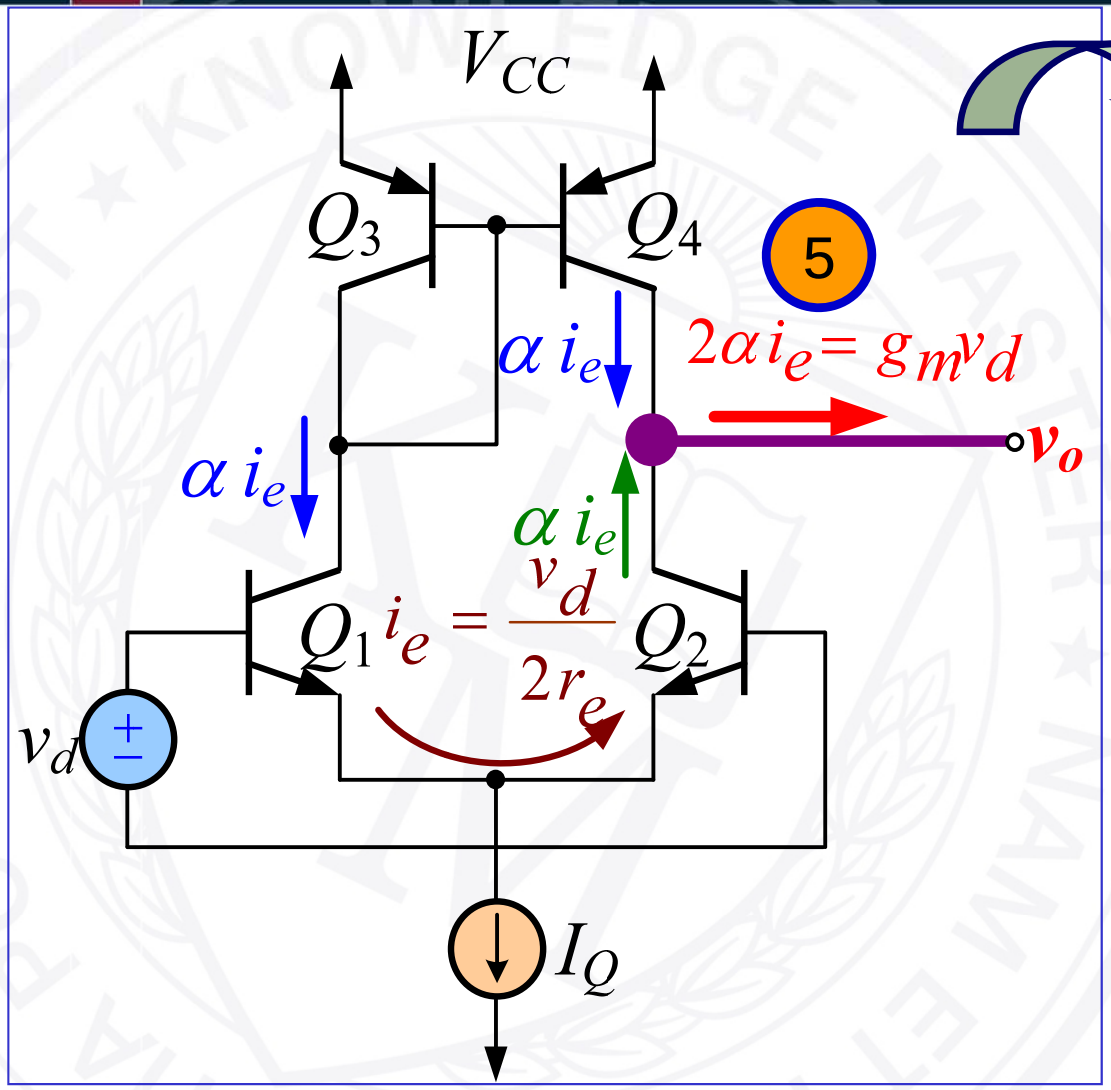
Analysis-by-Inspection

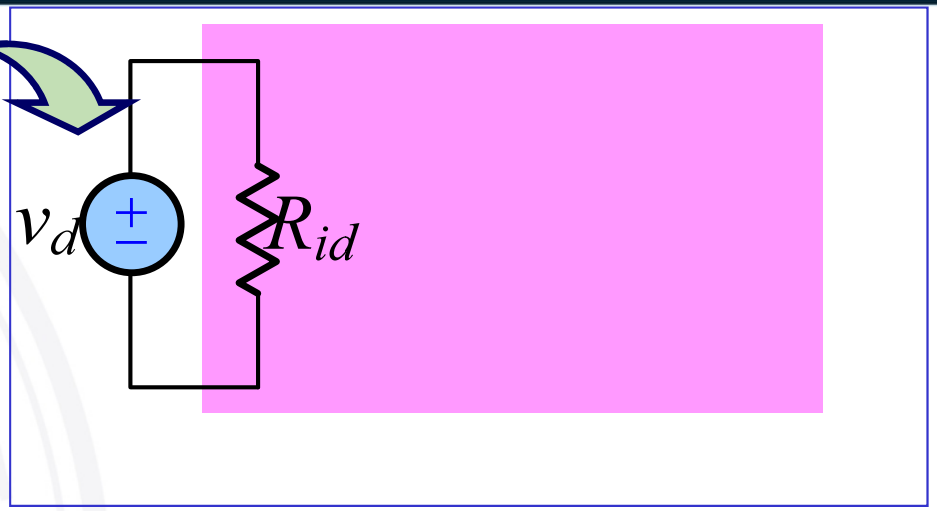


Analysis-by-Inspection

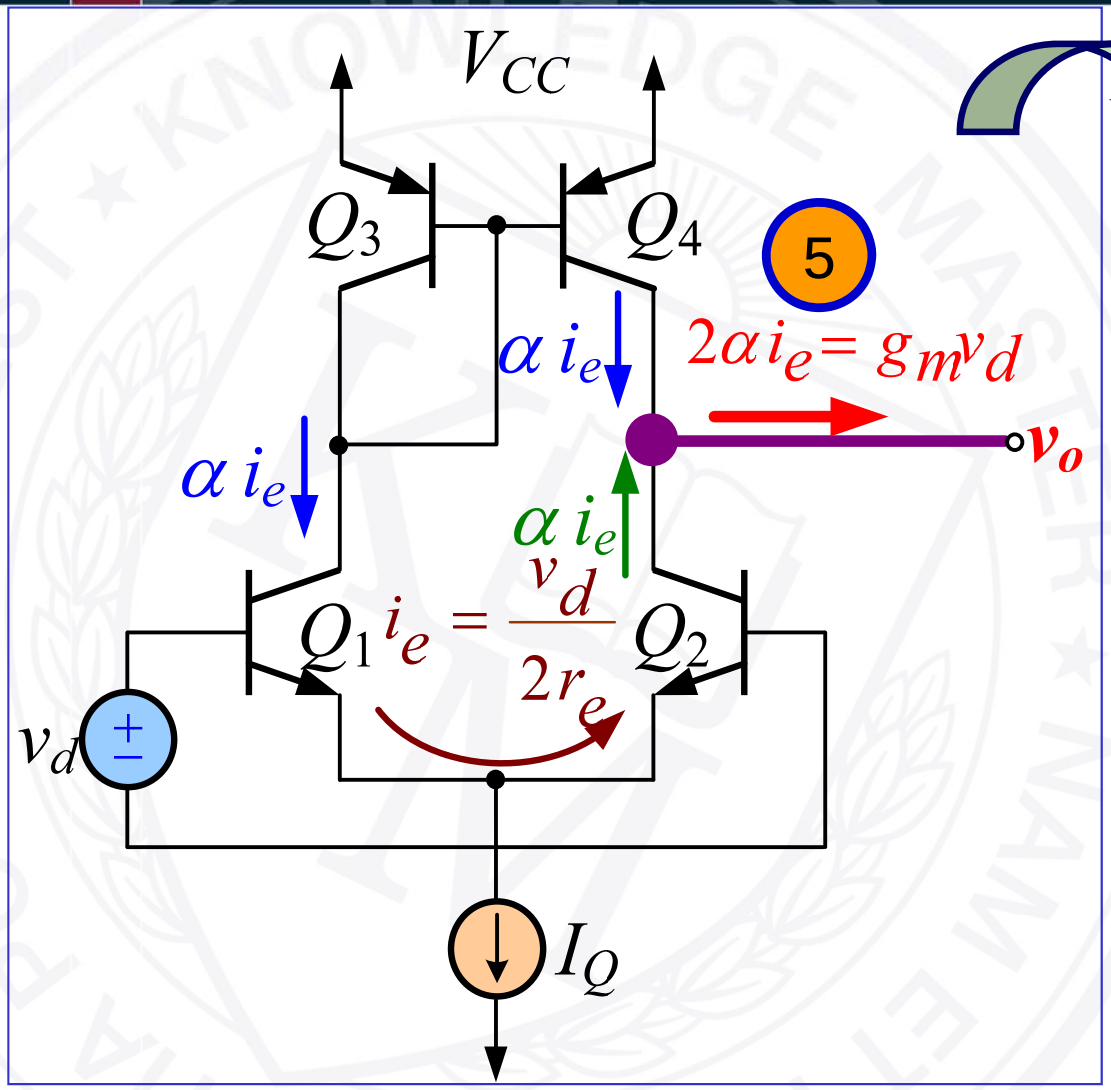


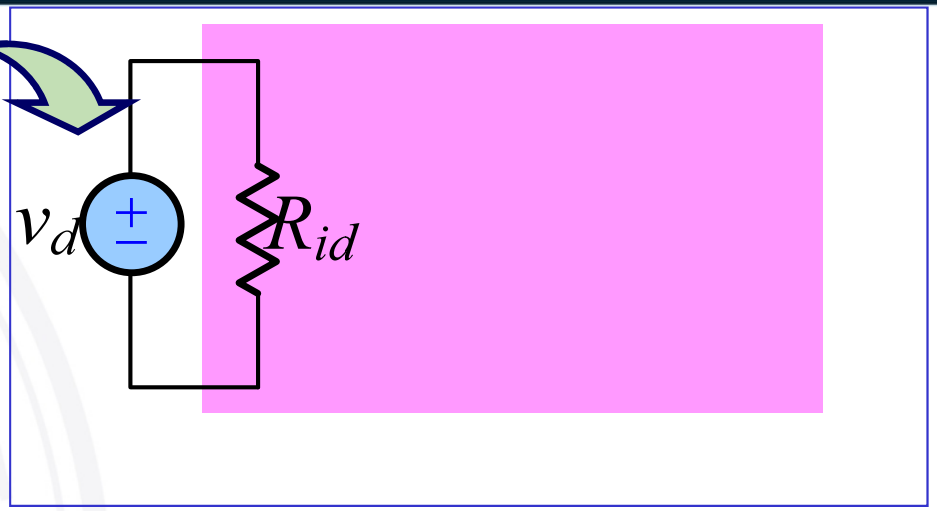
Equivalent Circuit





Finesse—Norton Equivalent Circuit





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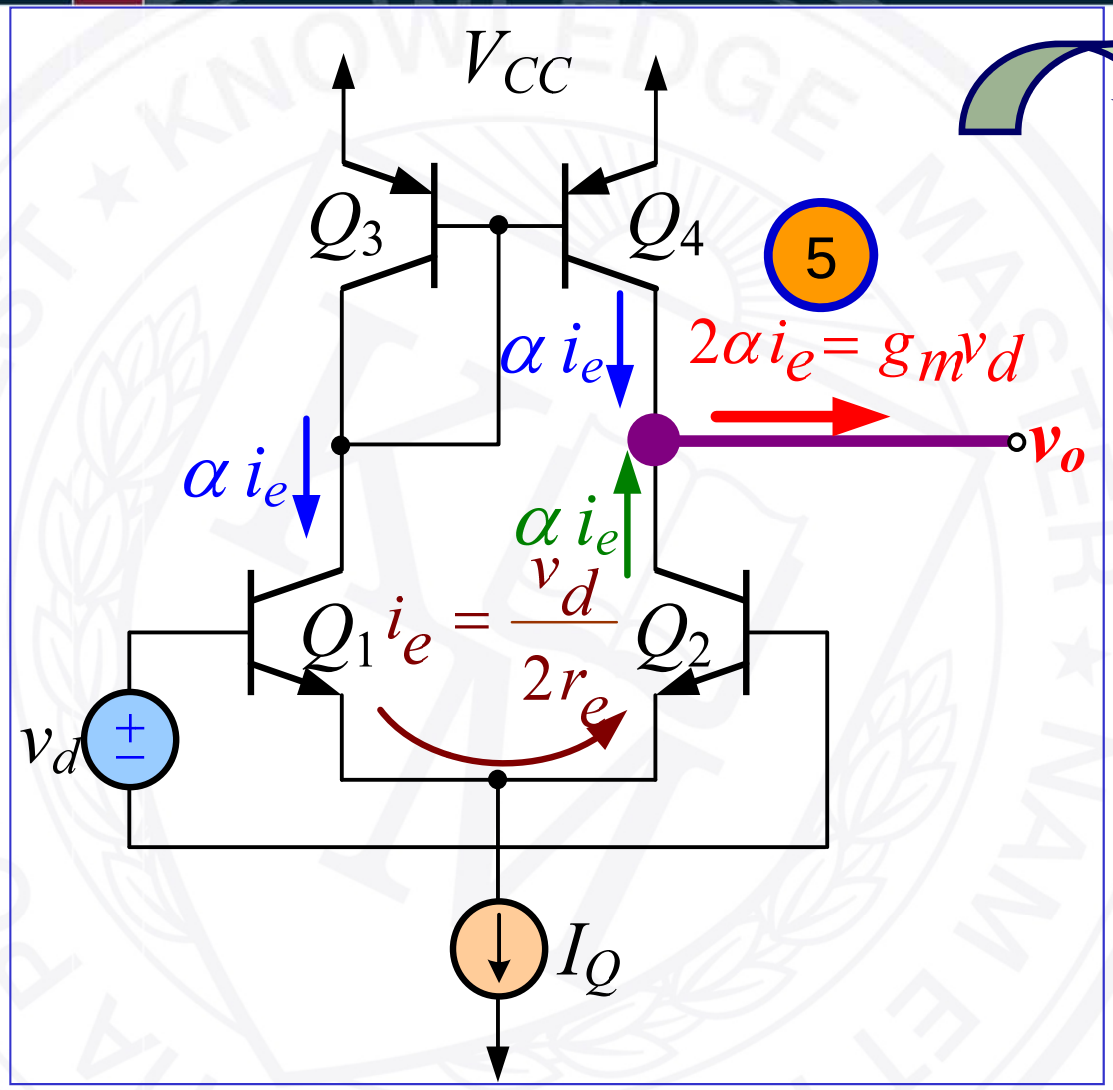
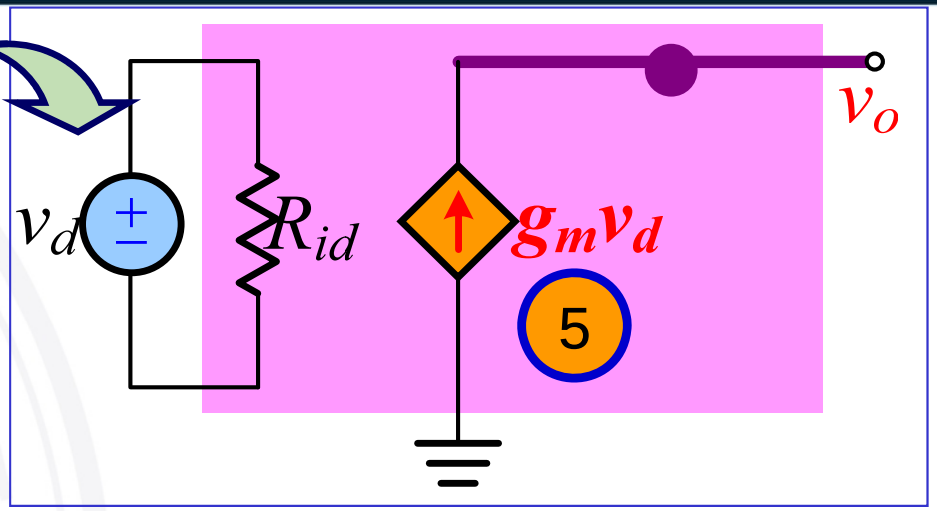
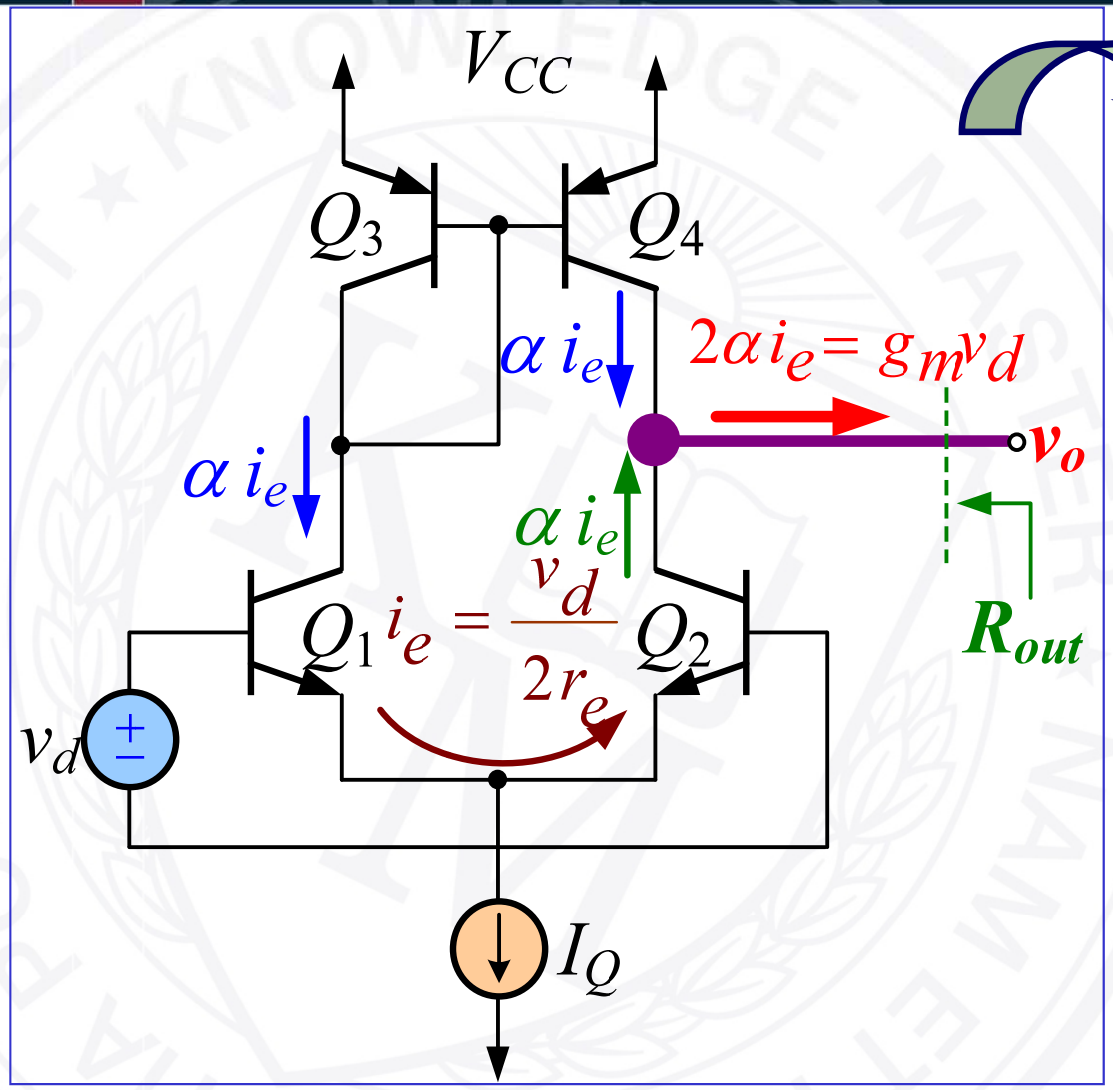
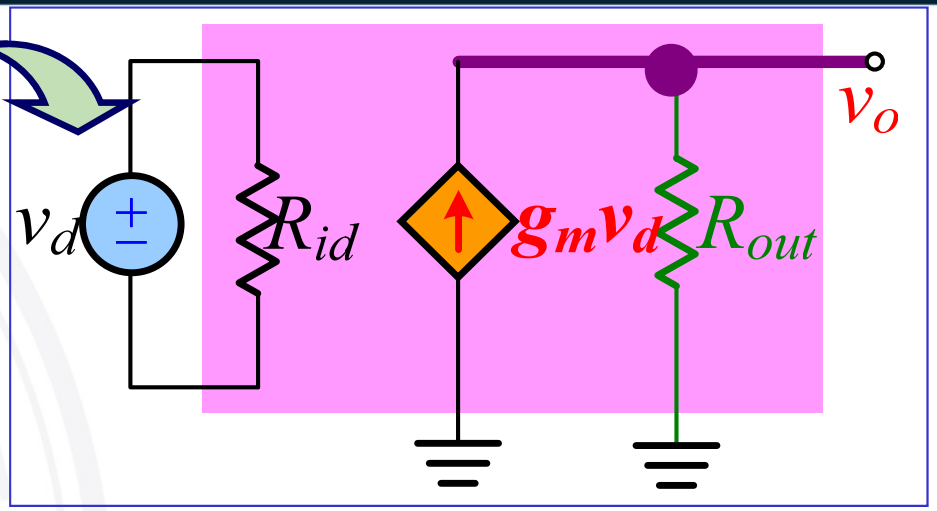


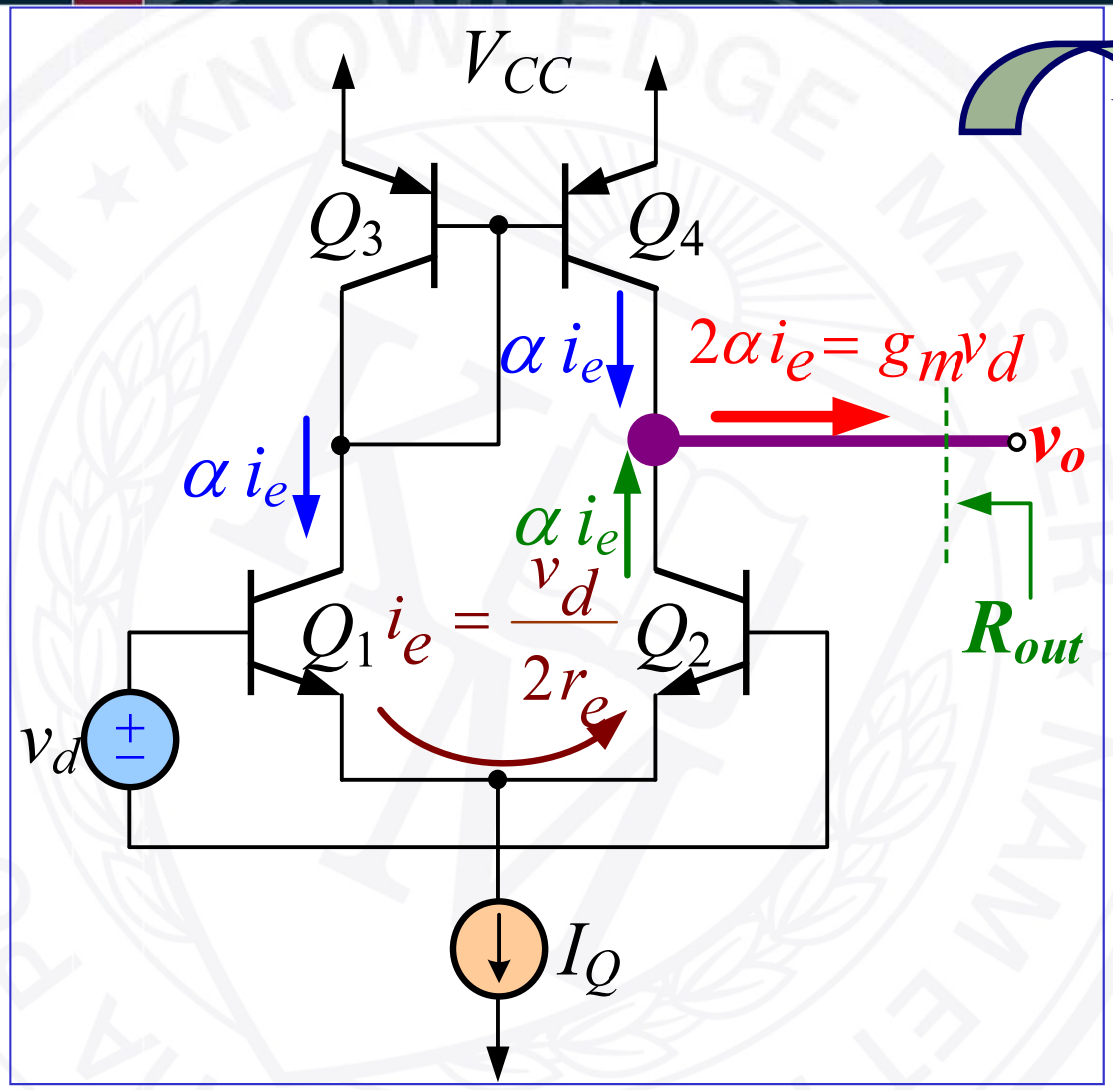


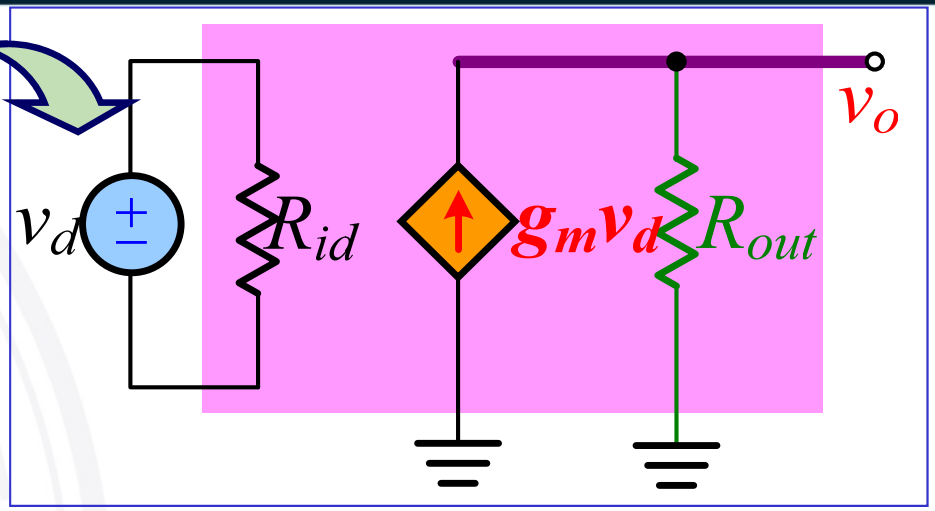
Finesse—Norton Equivalent Circuit





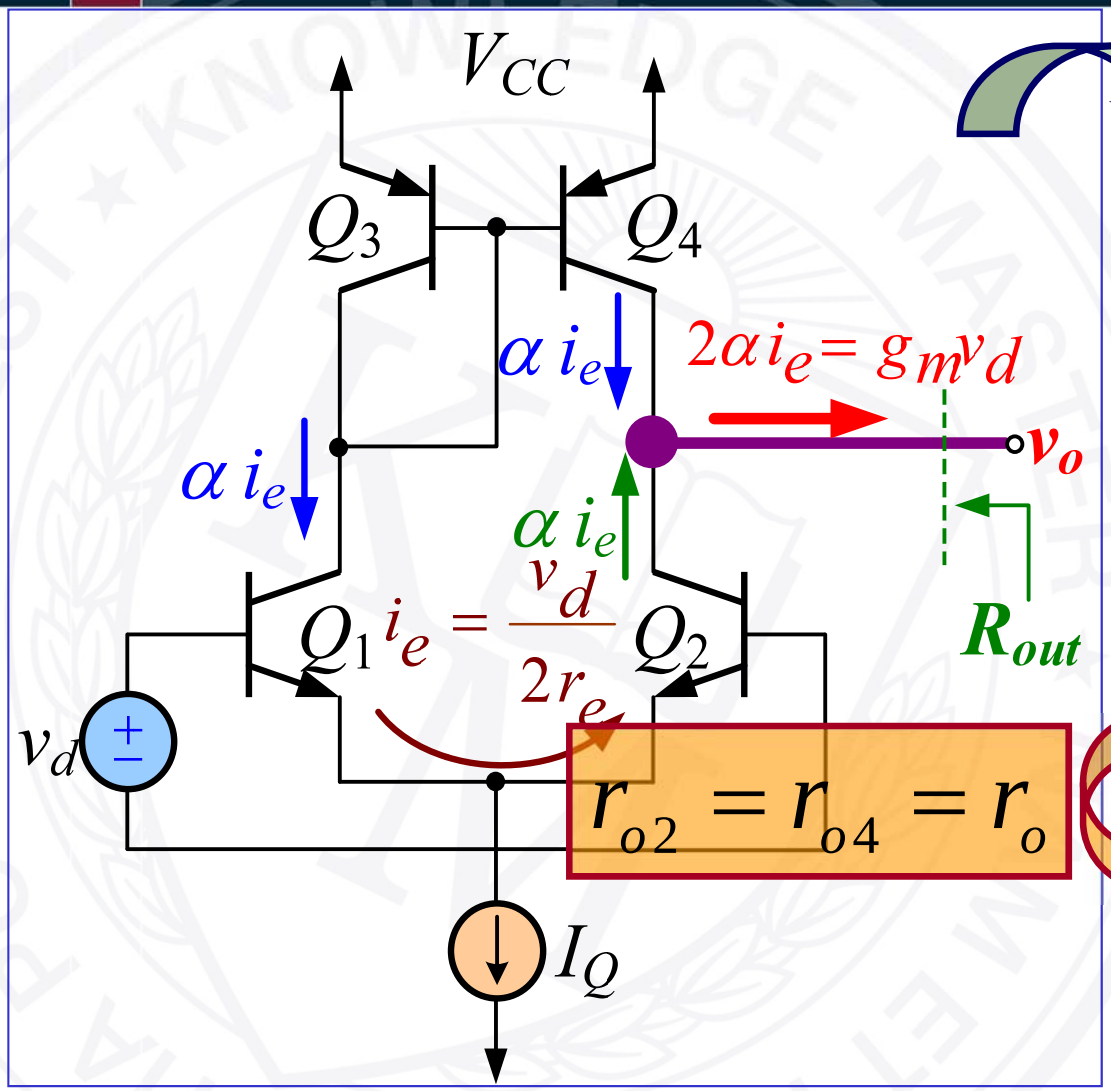
Open-Circuit Voltage Gain

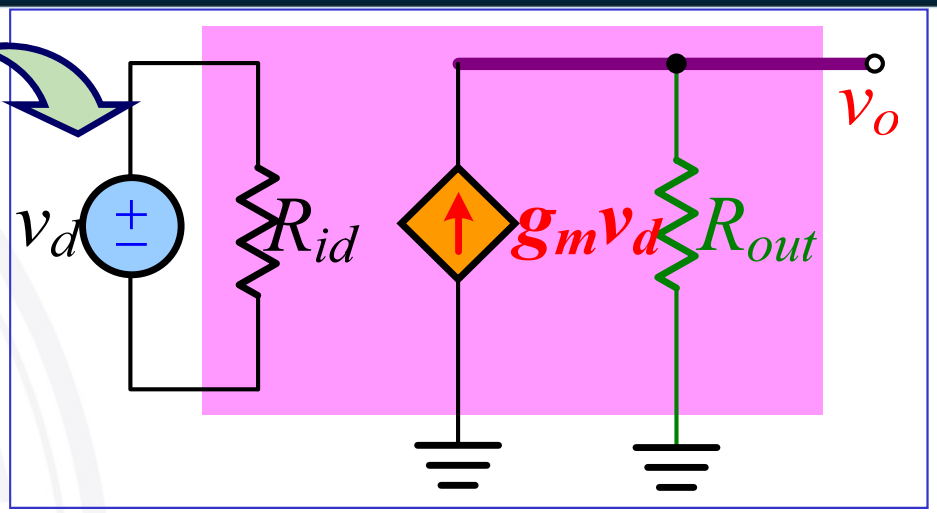




$$A_d \triangleq \frac{v_o}{v_d} = g_m R_{out}$$

Differential Gain





$$A_d \triangleq \frac{v_o}{v_d} = g_m R_{out} = g_m (r_{o2} \| r_{o4})$$

$$A_d \triangleq \frac{v_o}{v_d} = \frac{1}{2} g_m r_o = \frac{1}{2} \frac{V_A}{V_T}$$

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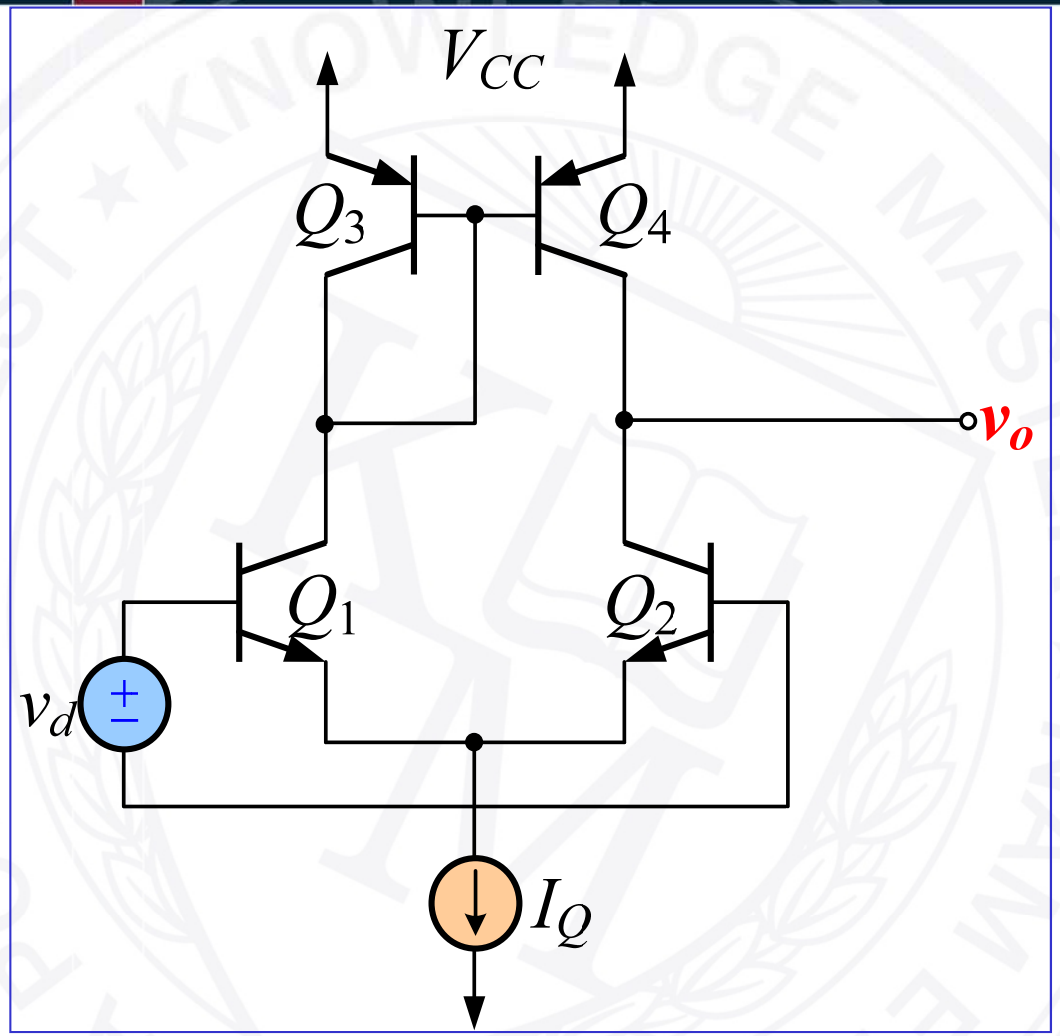
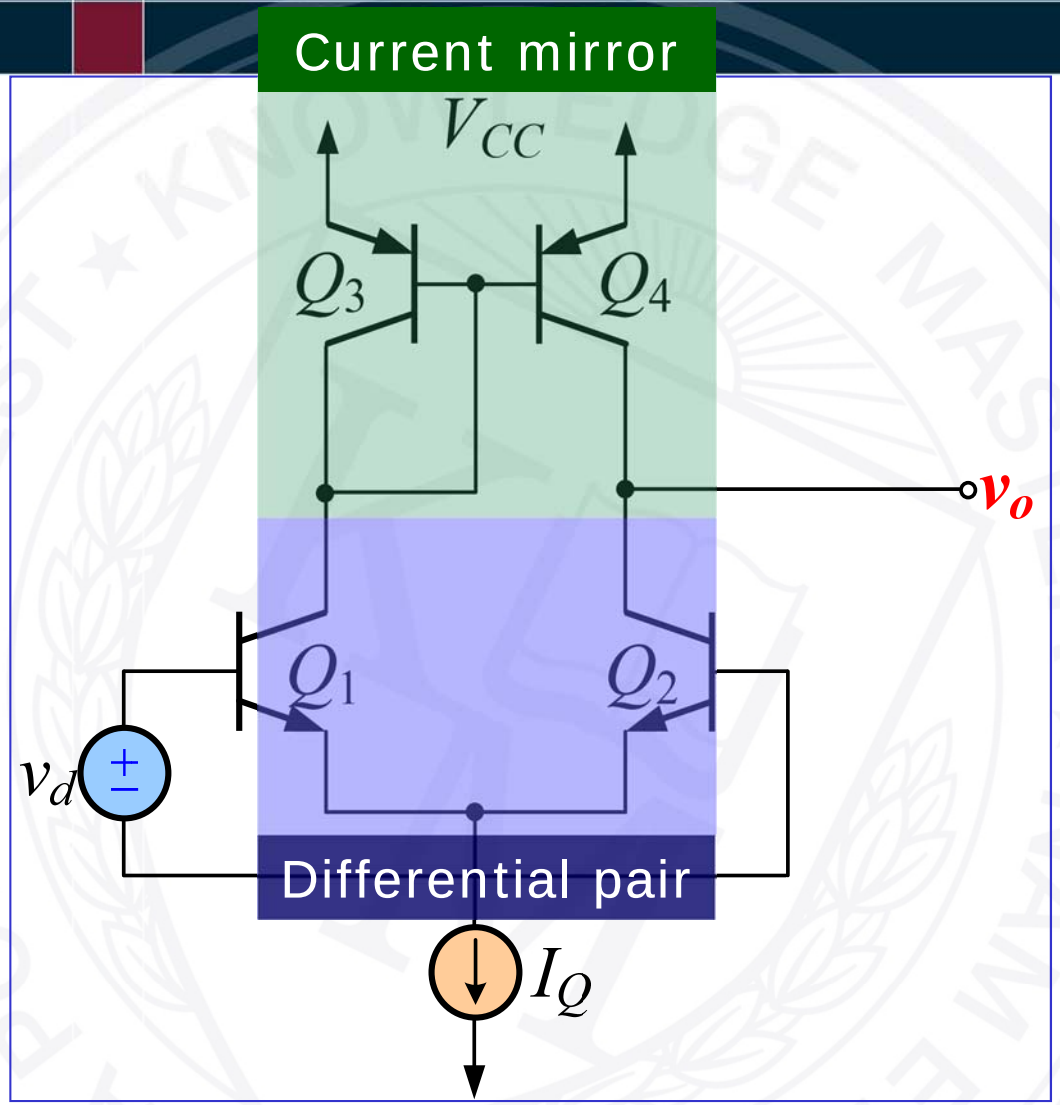
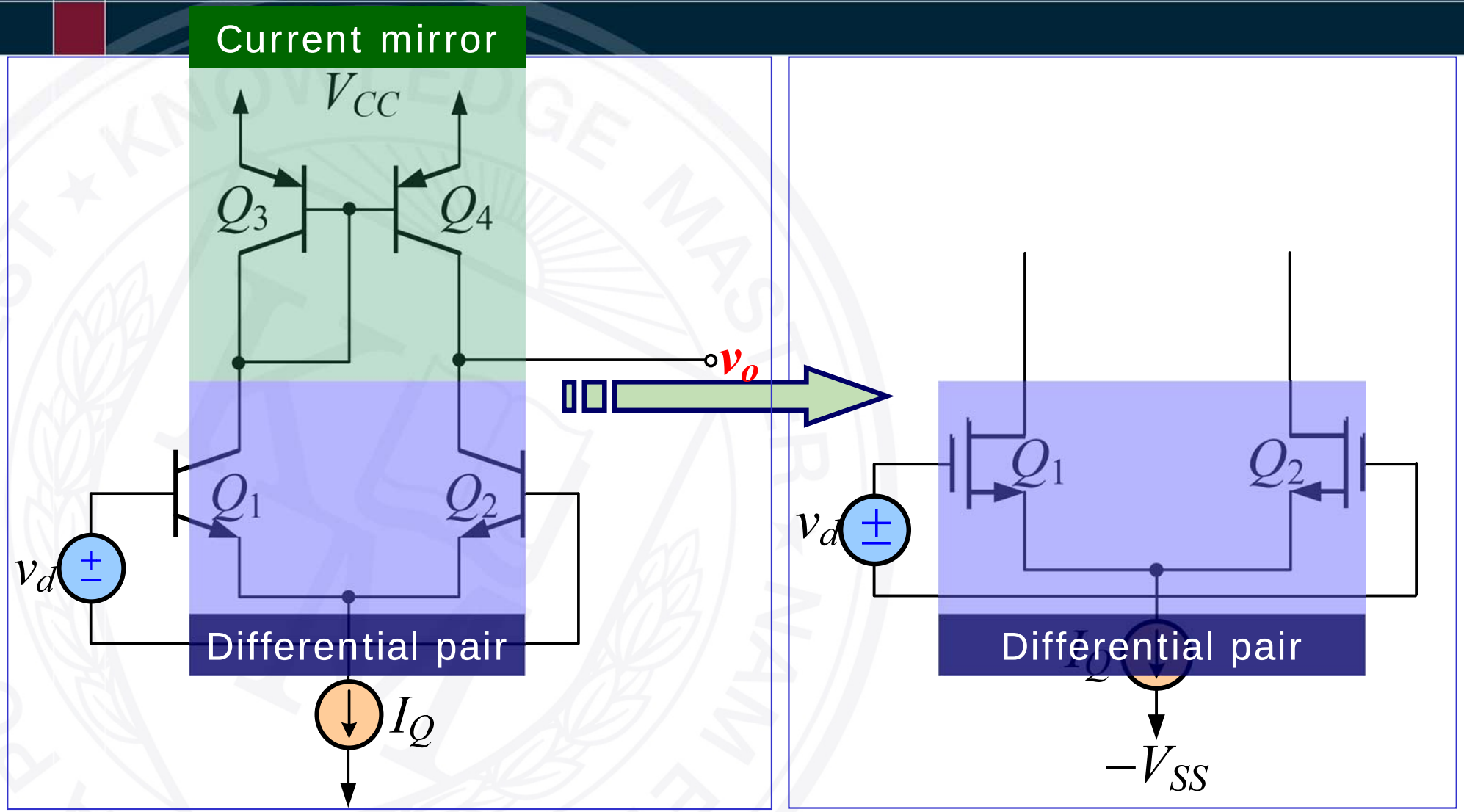
BJT Differential Amplifier



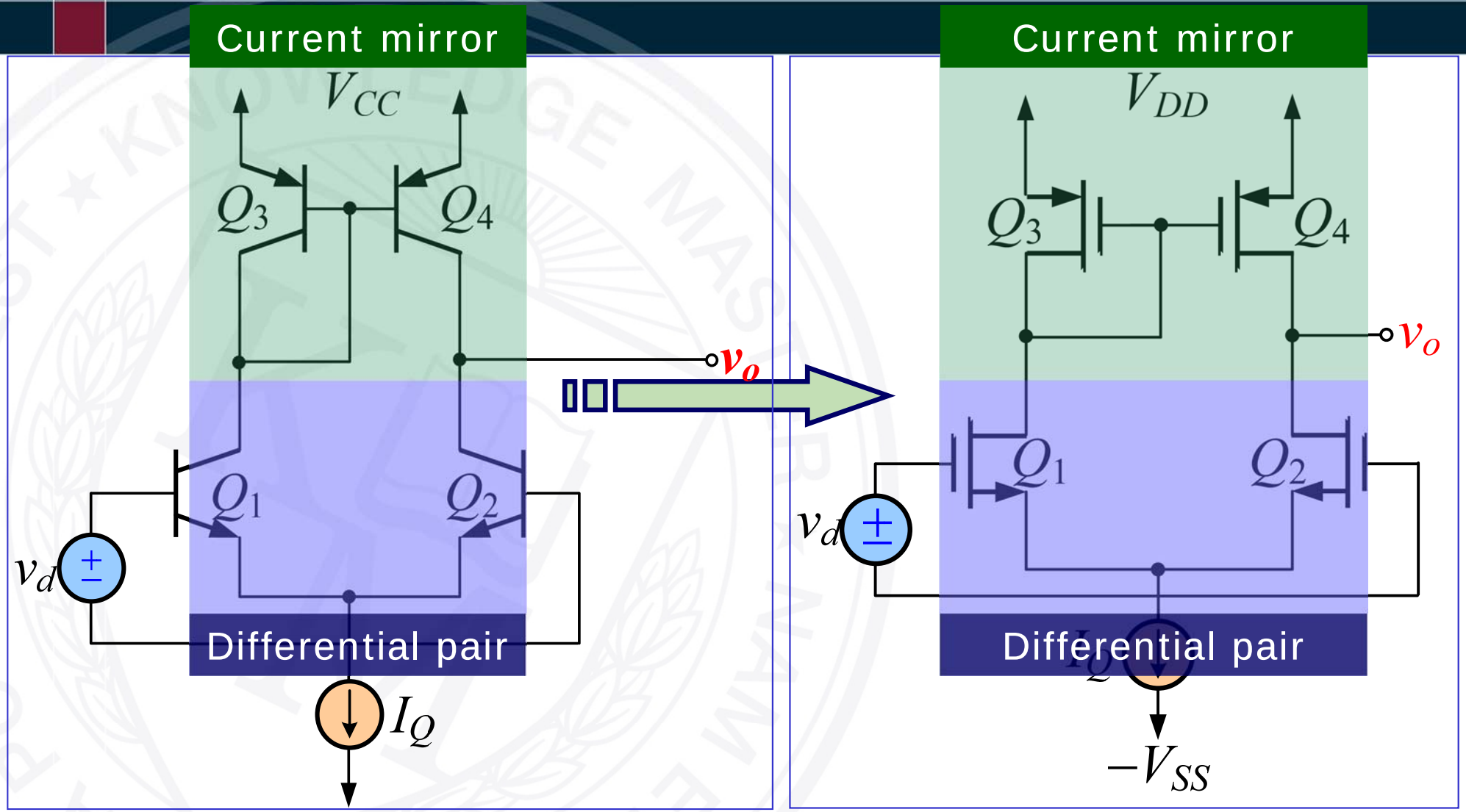
BJT Differential Amplifier



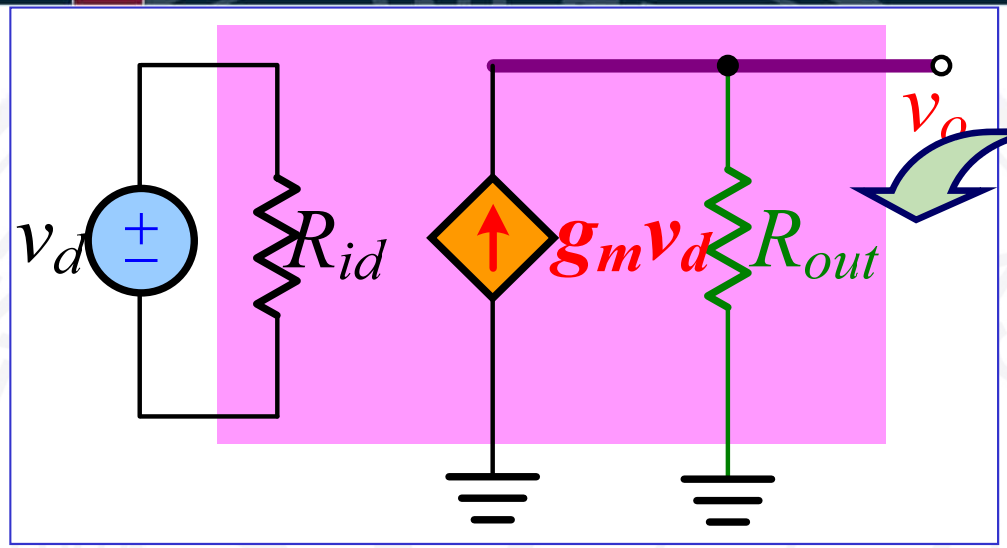
BJT vs. CMOS D-Amp

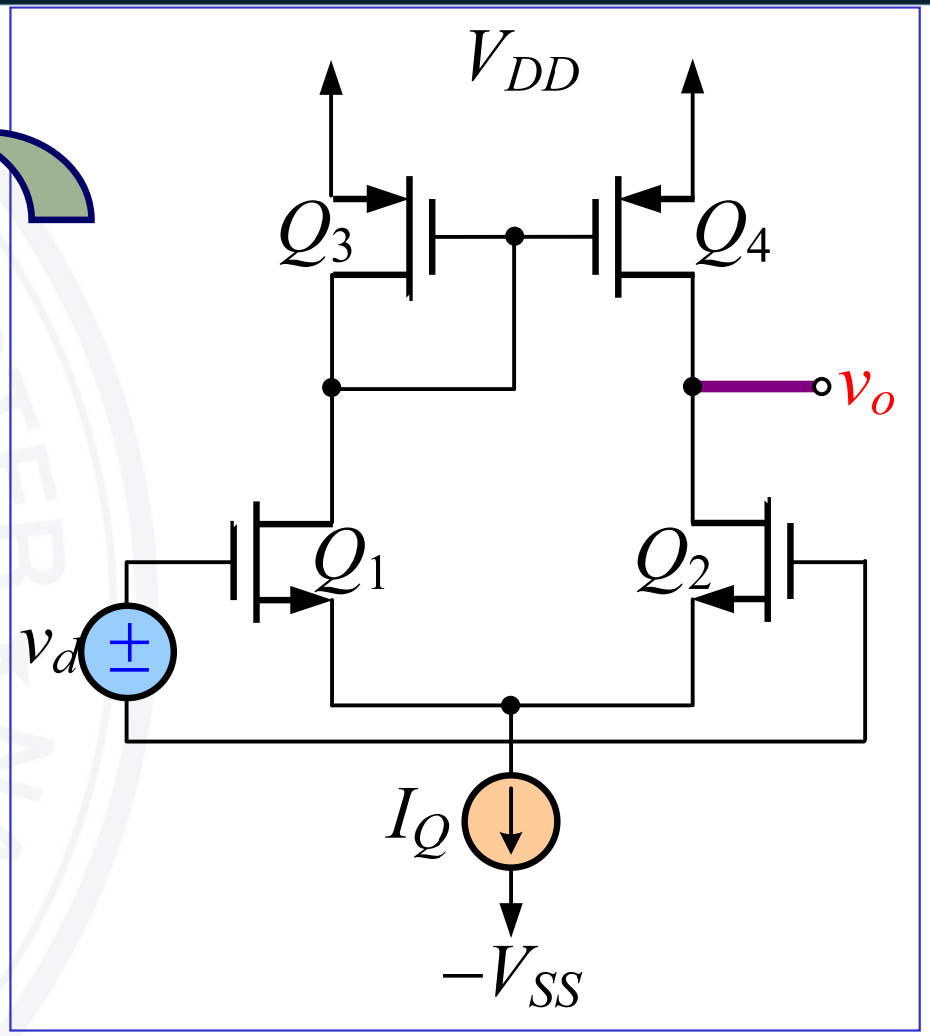


BJT vs. CMOS Differential Amplifier

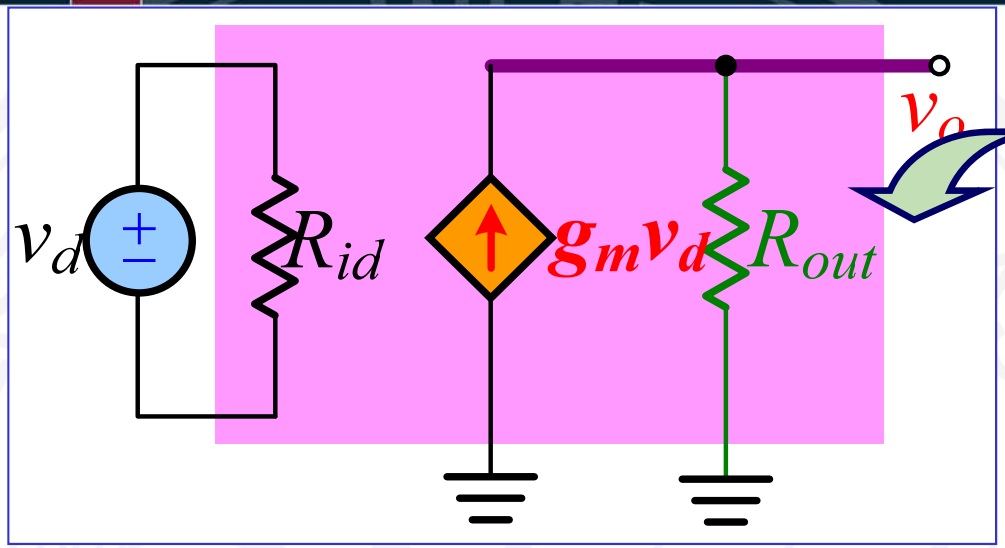


CMOS Differential Amplifier

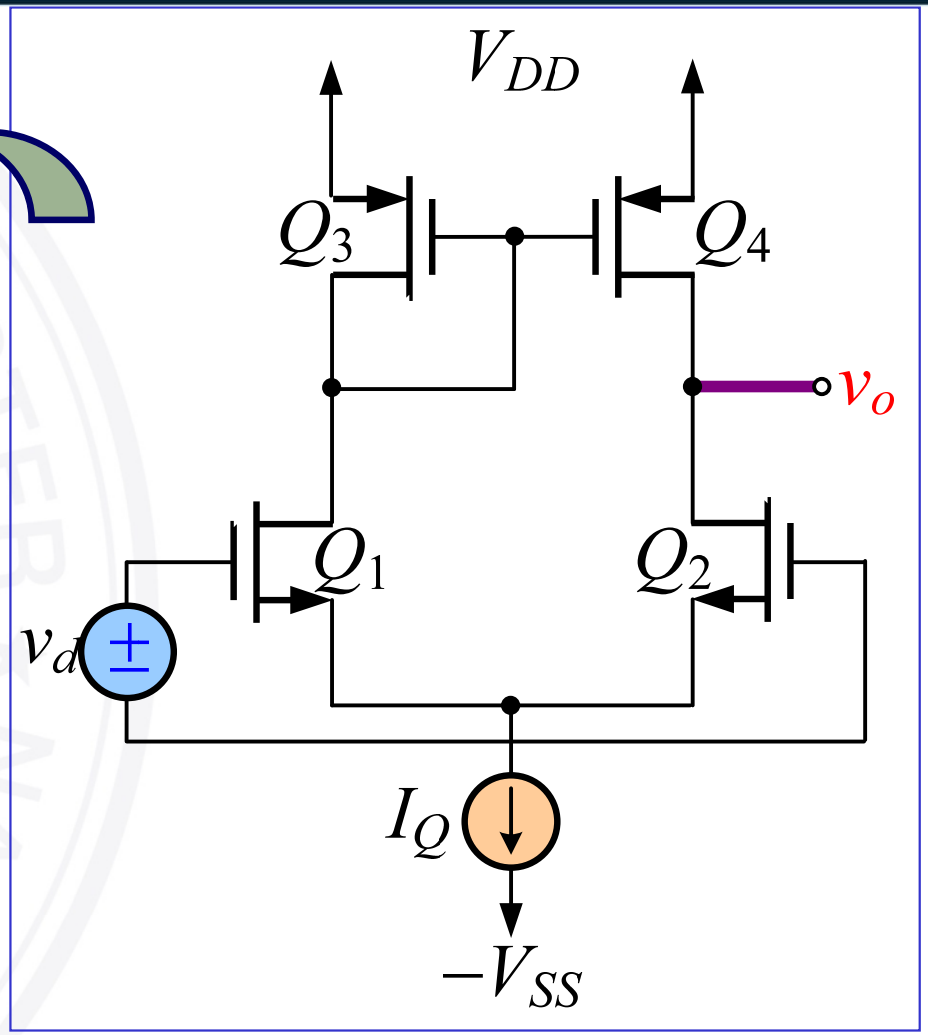




Gain



$$A_d \triangleq \frac{v_o}{v_d} = g_m R_{out} = \frac{1}{2} g_m r_o$$



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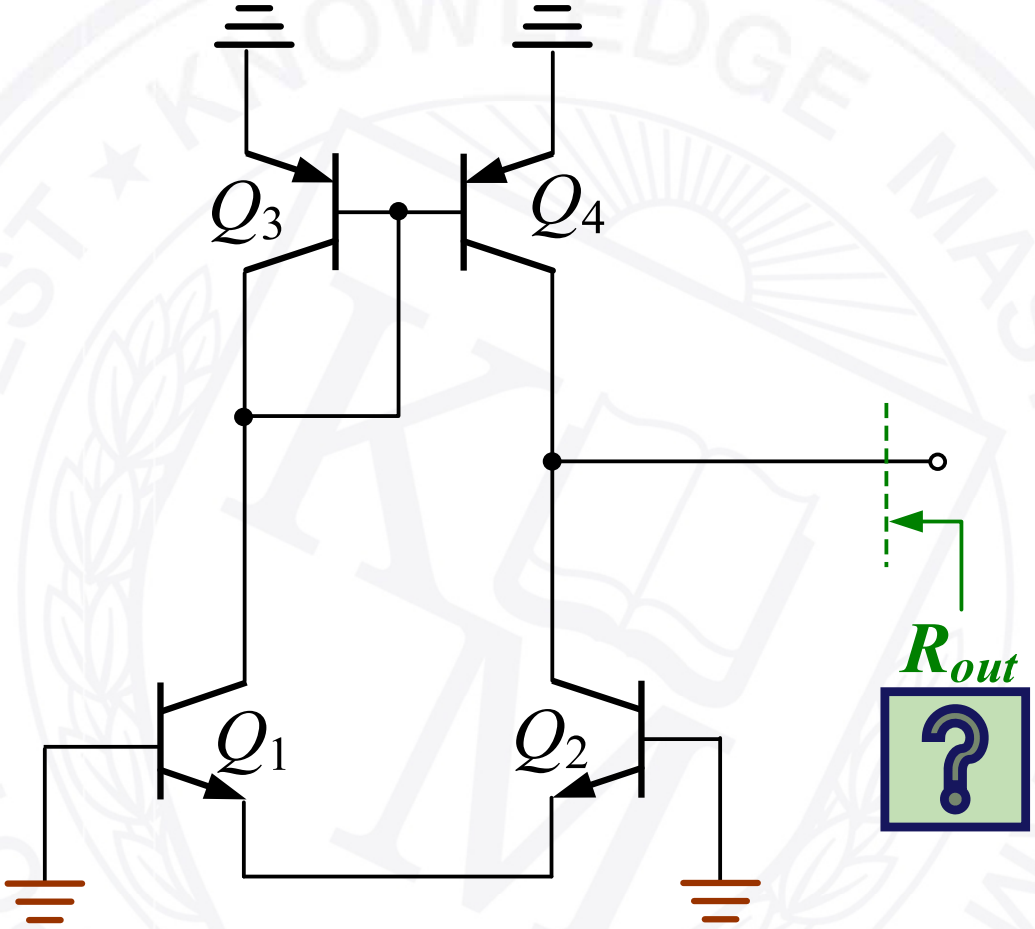
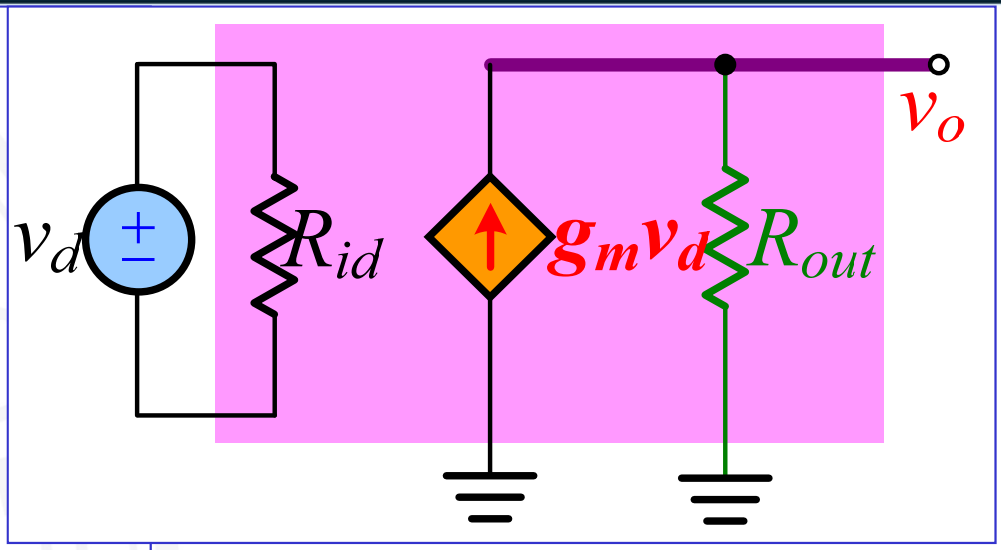
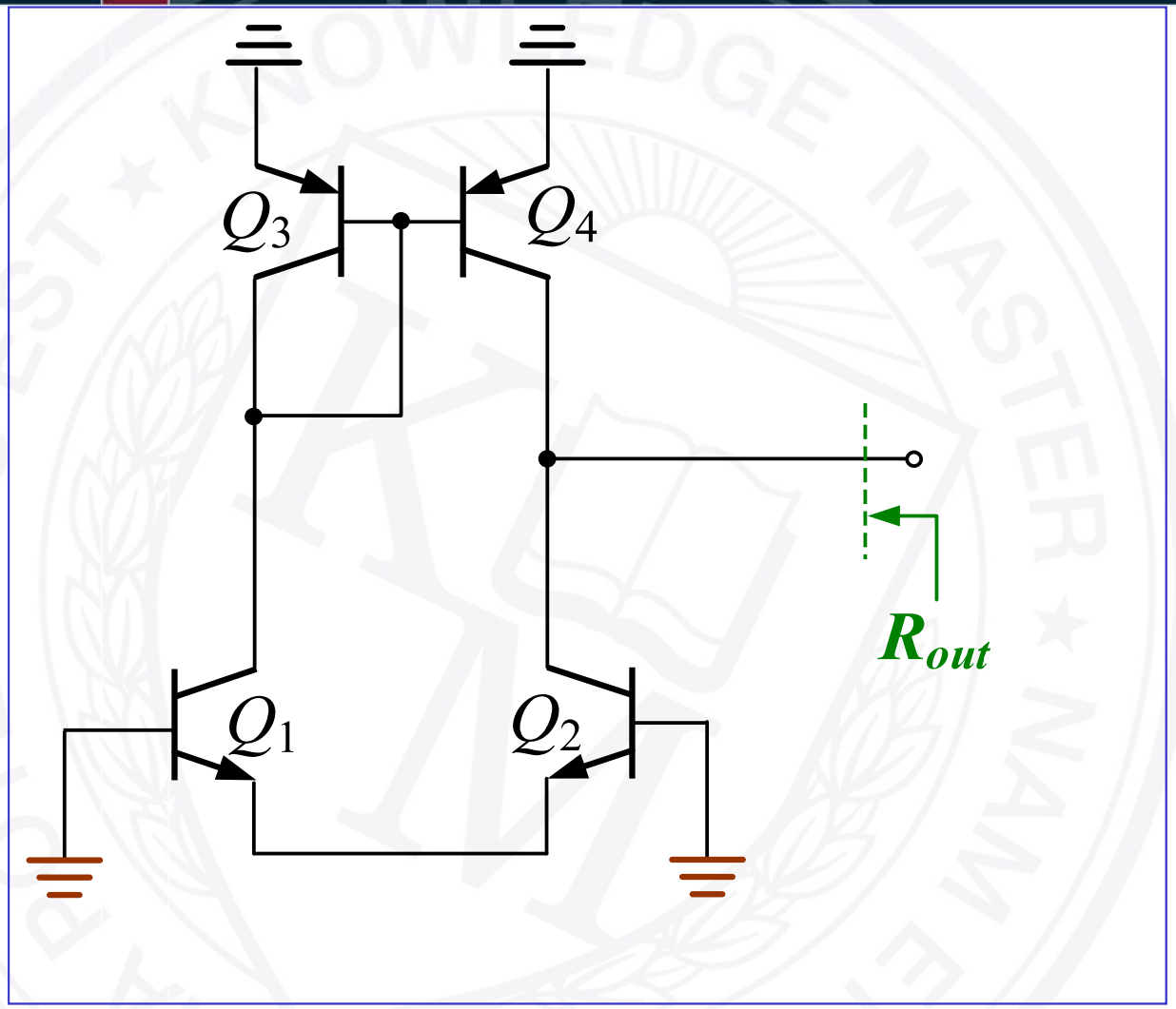


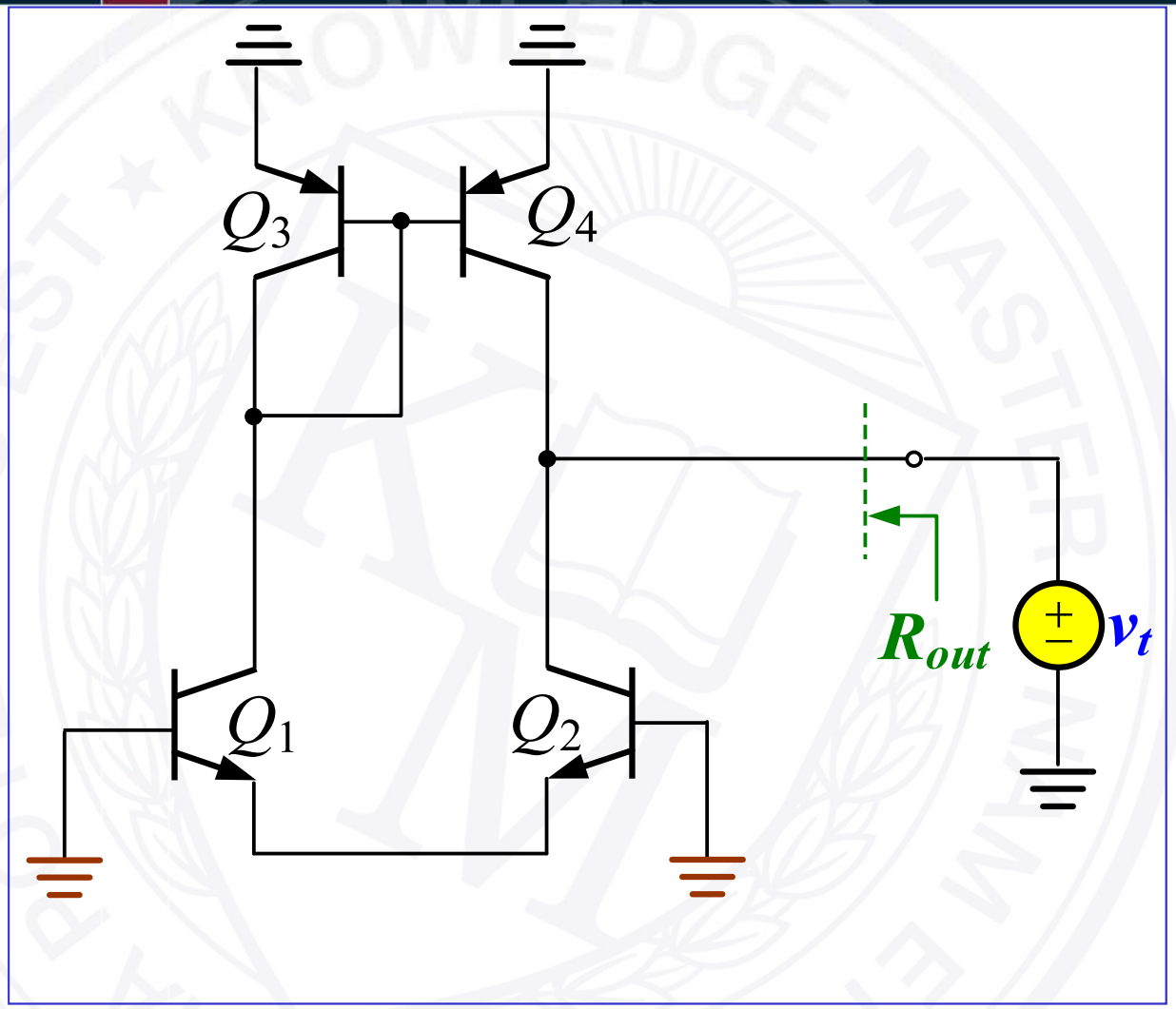


$$A_d \triangleq \frac{v_o}{v_d} = g_m R_{out} = g_m (r_{o2} \| r_{o4})$$

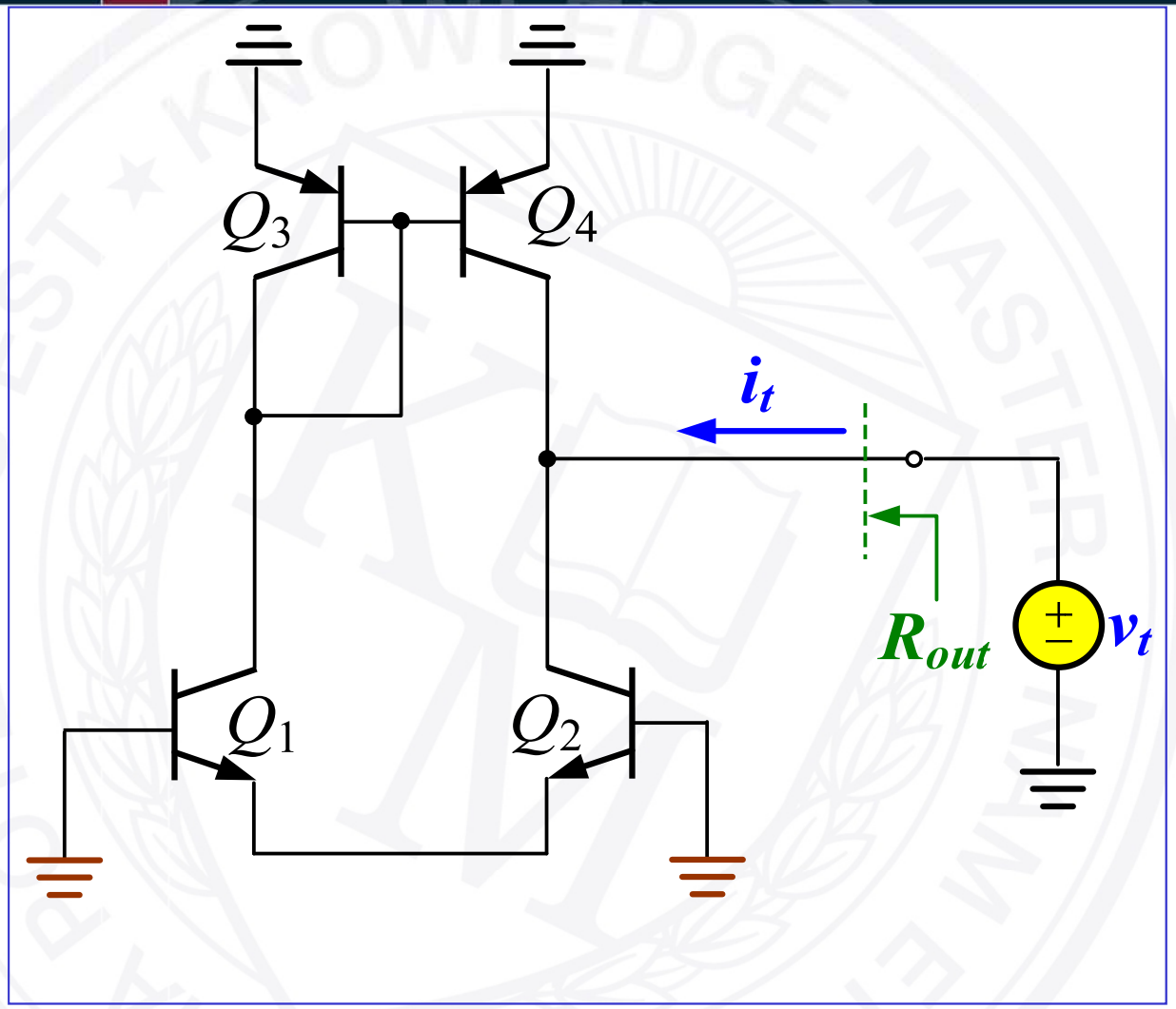
Output Resistance



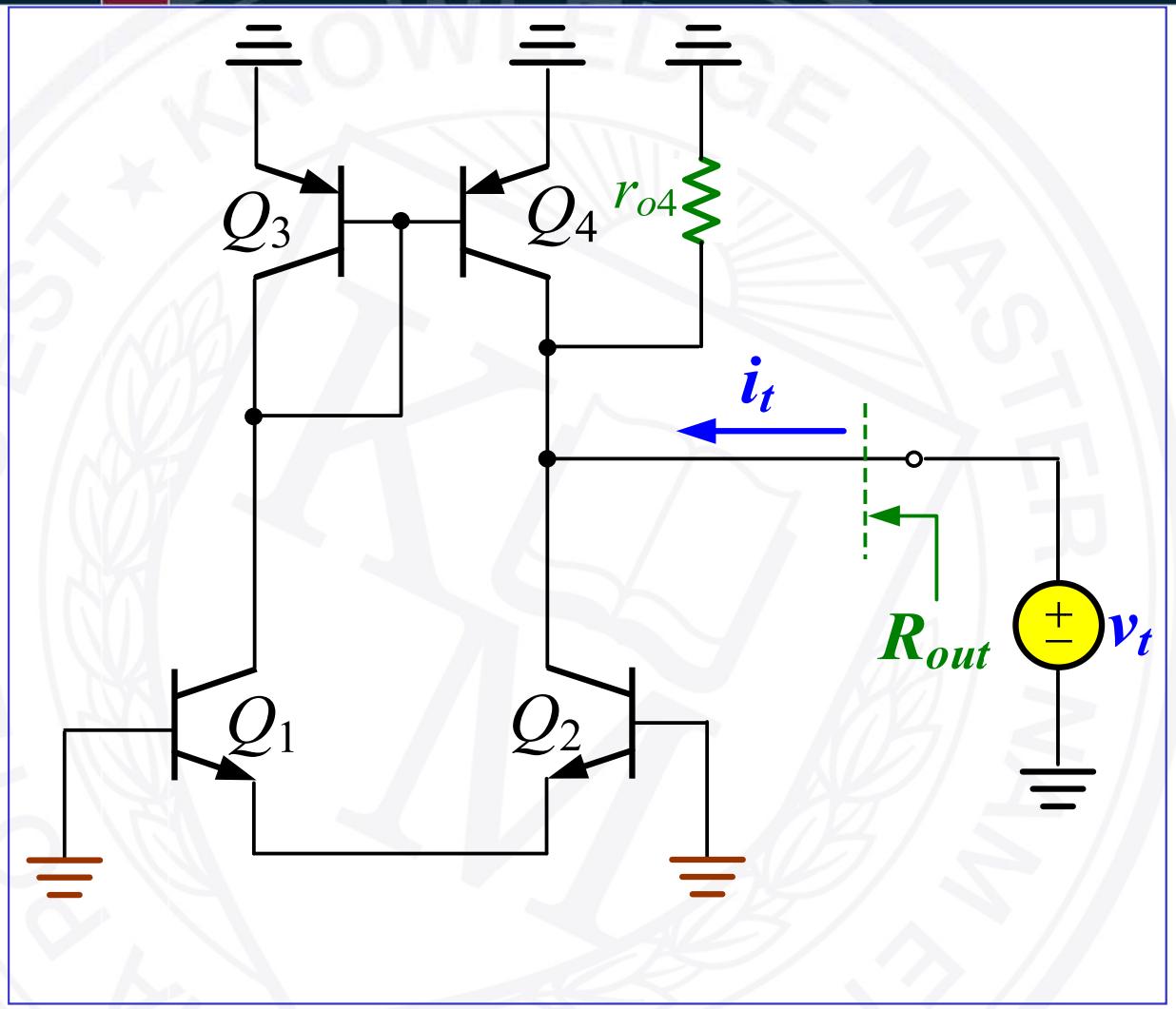
Output Resistance



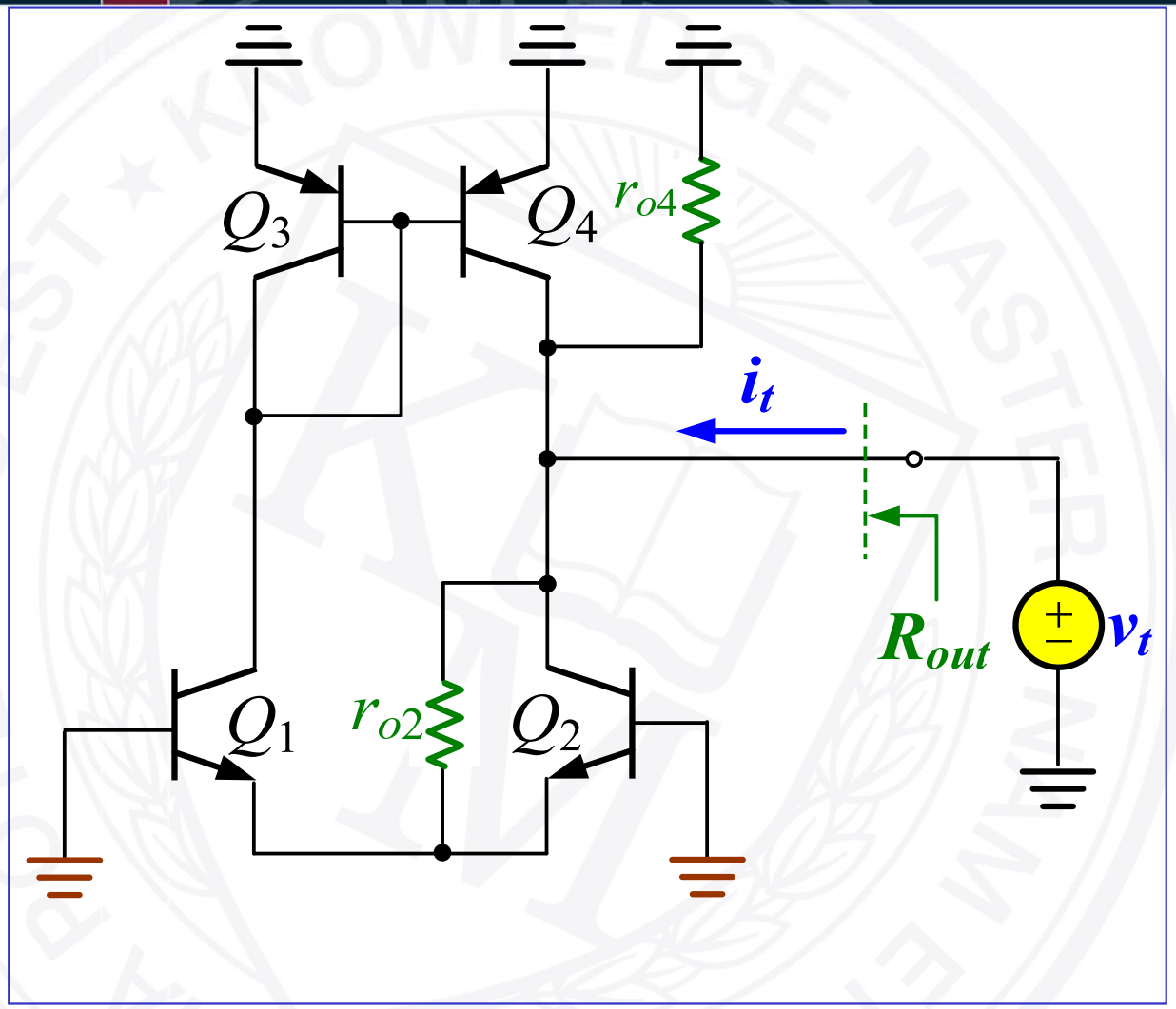
Output Resistance



Output Resistance



Output Resistance



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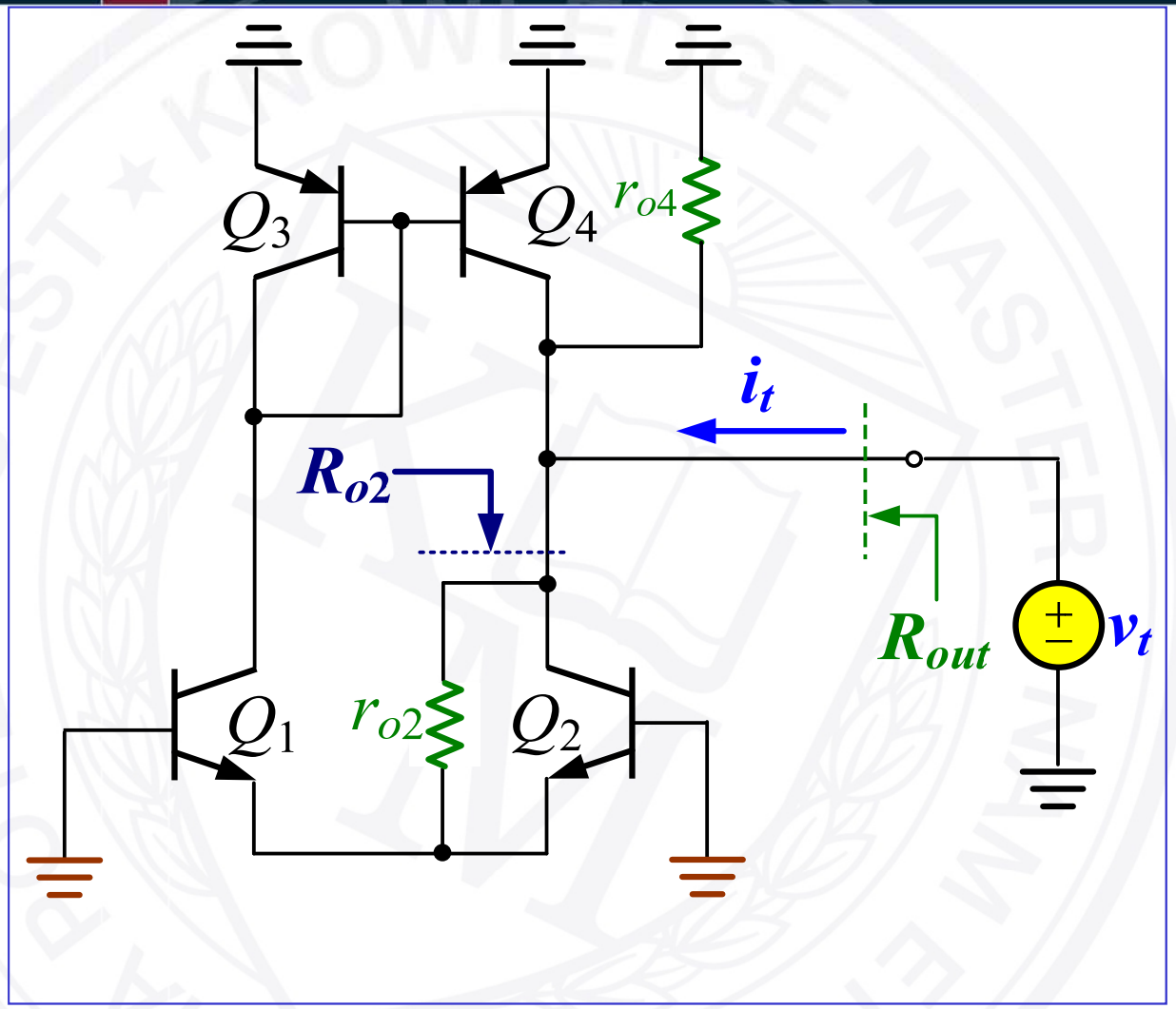

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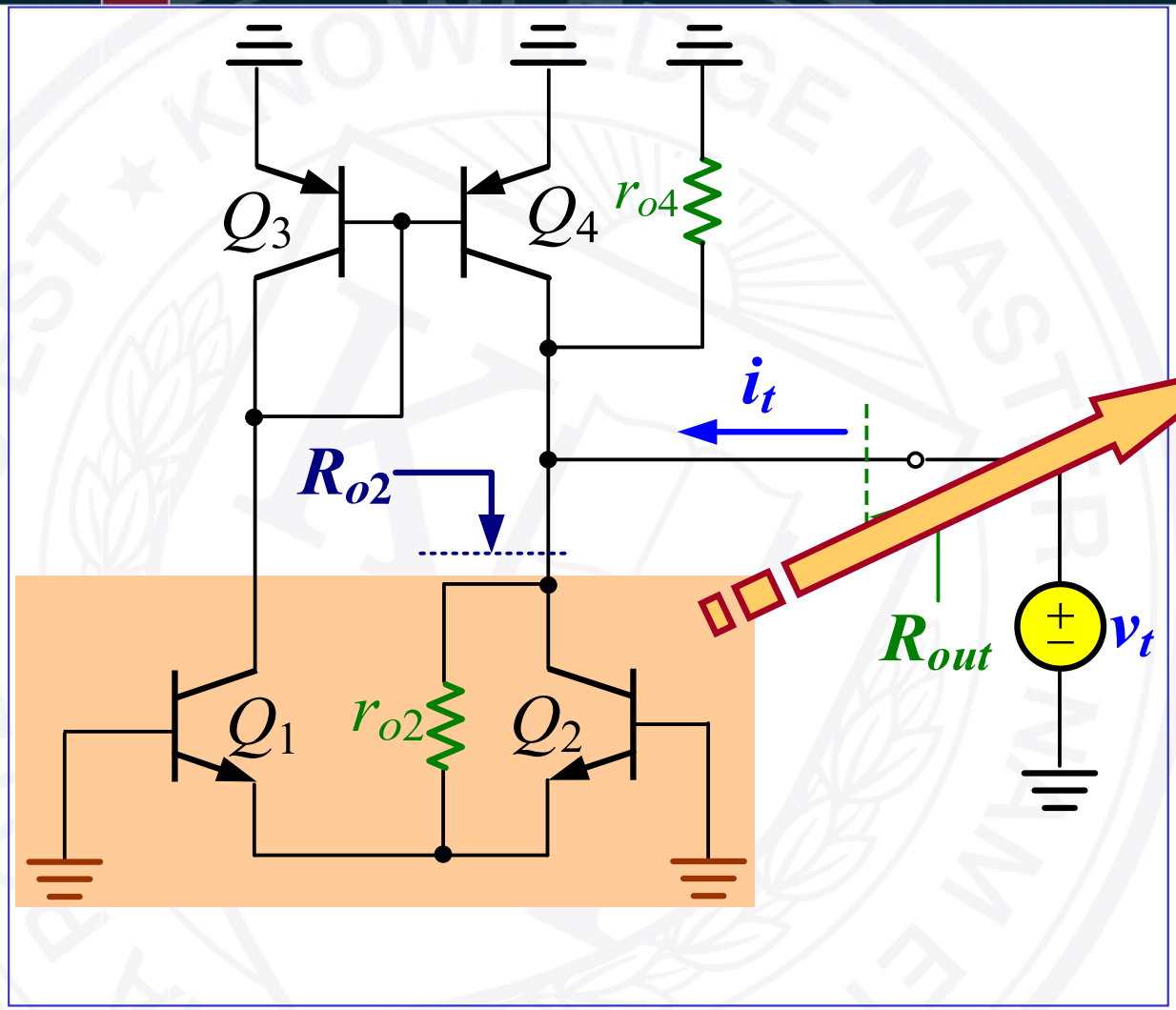
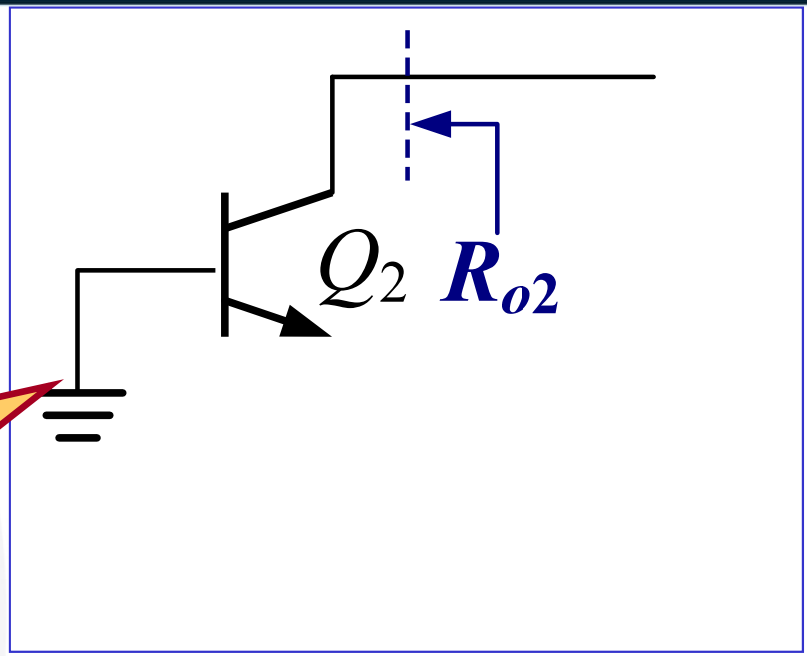
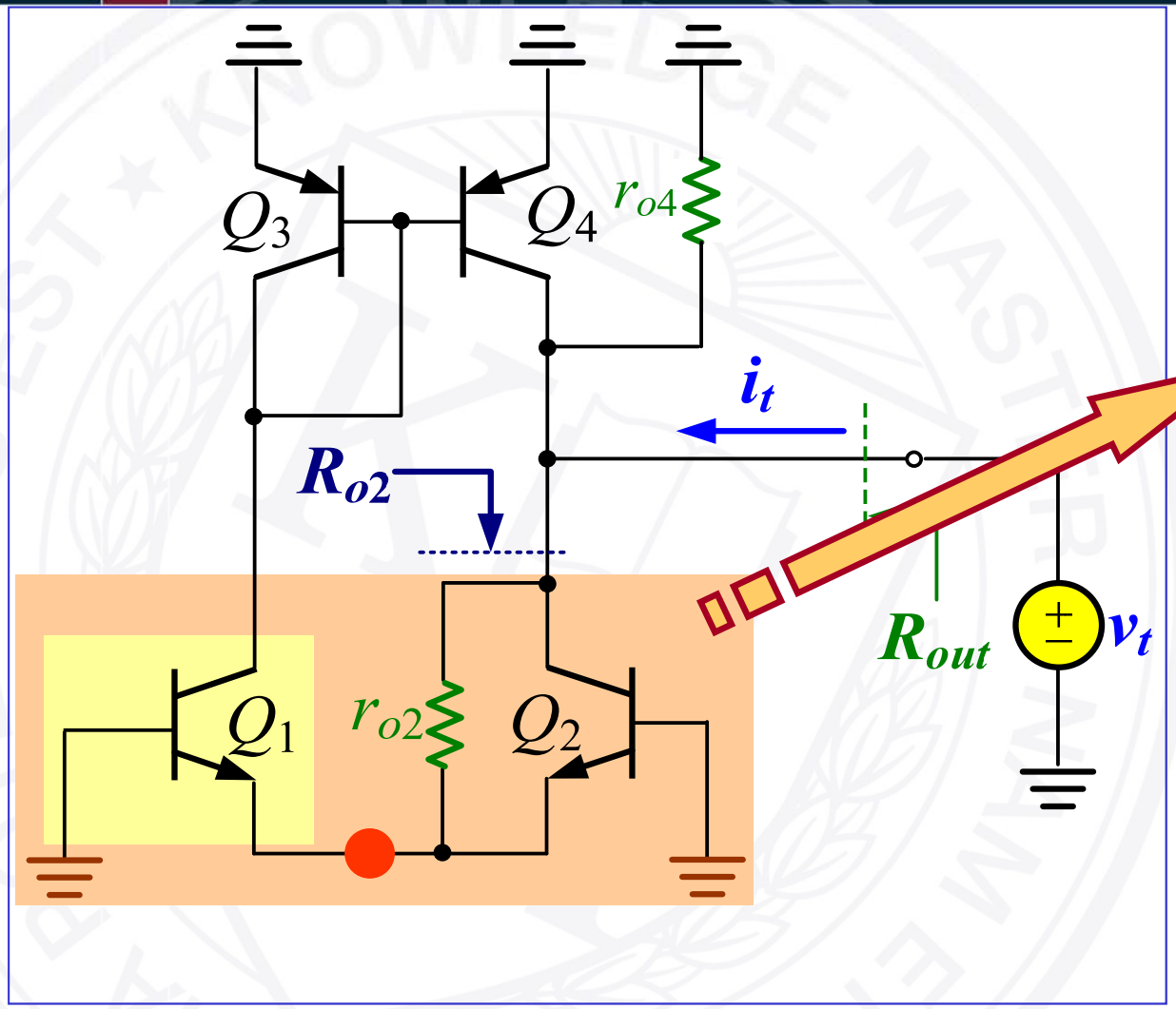
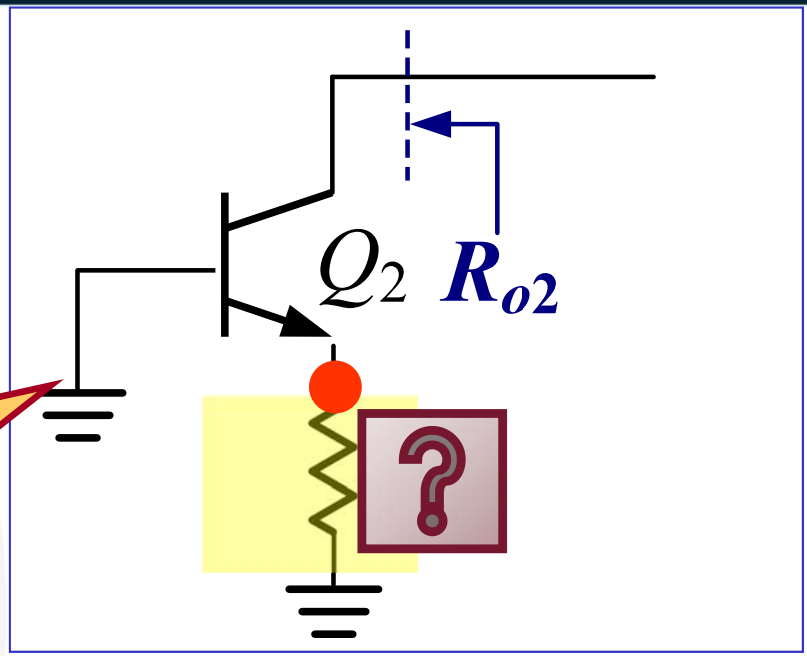




Output Resistance





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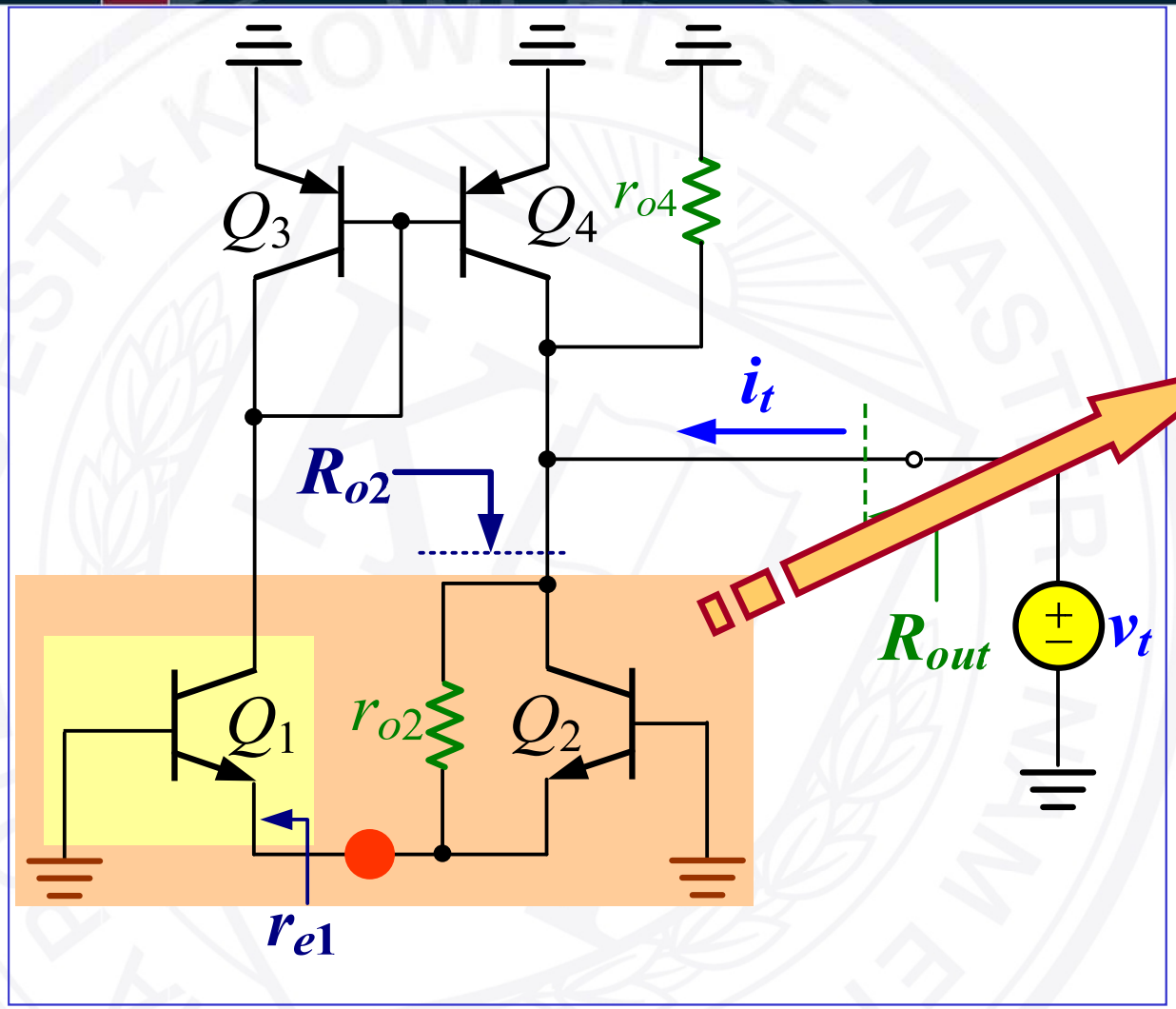

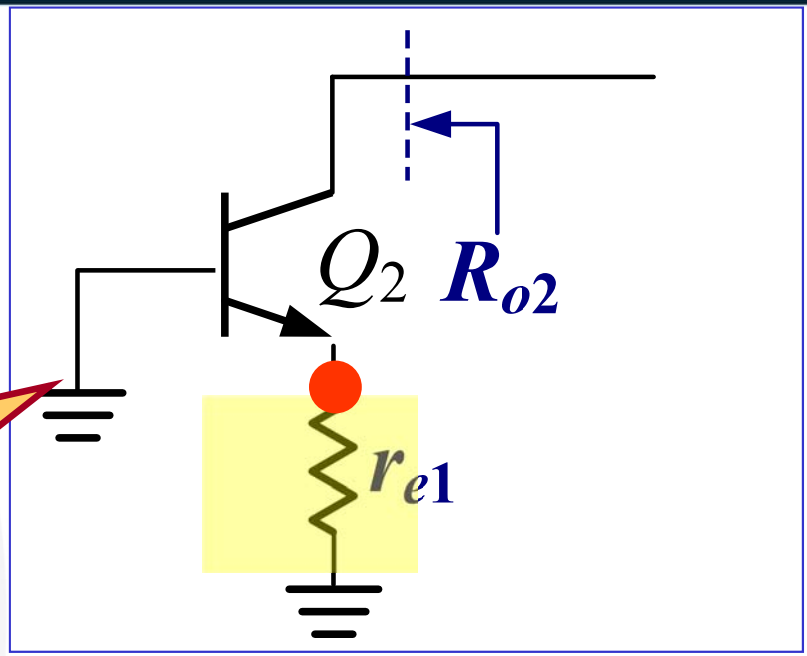

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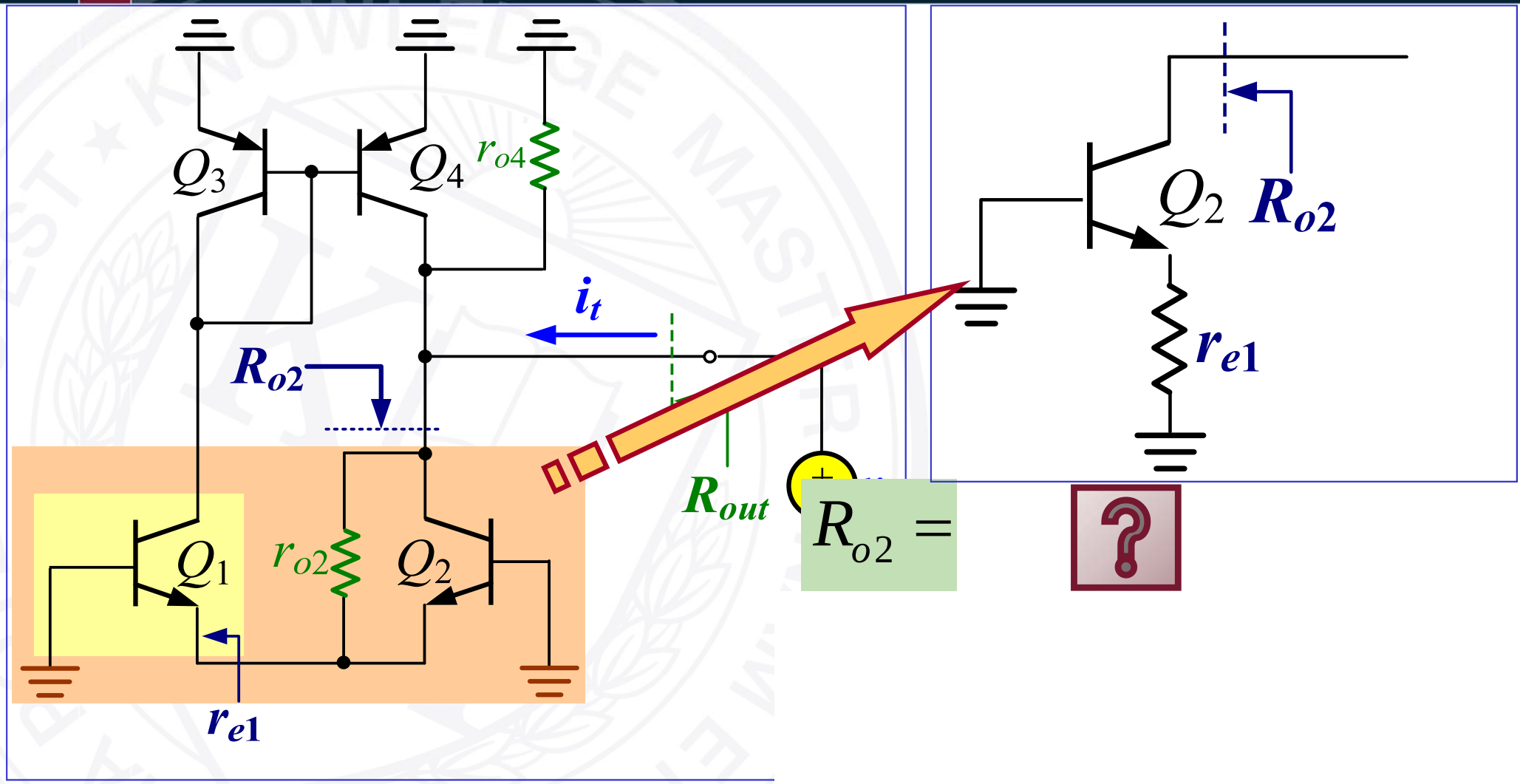

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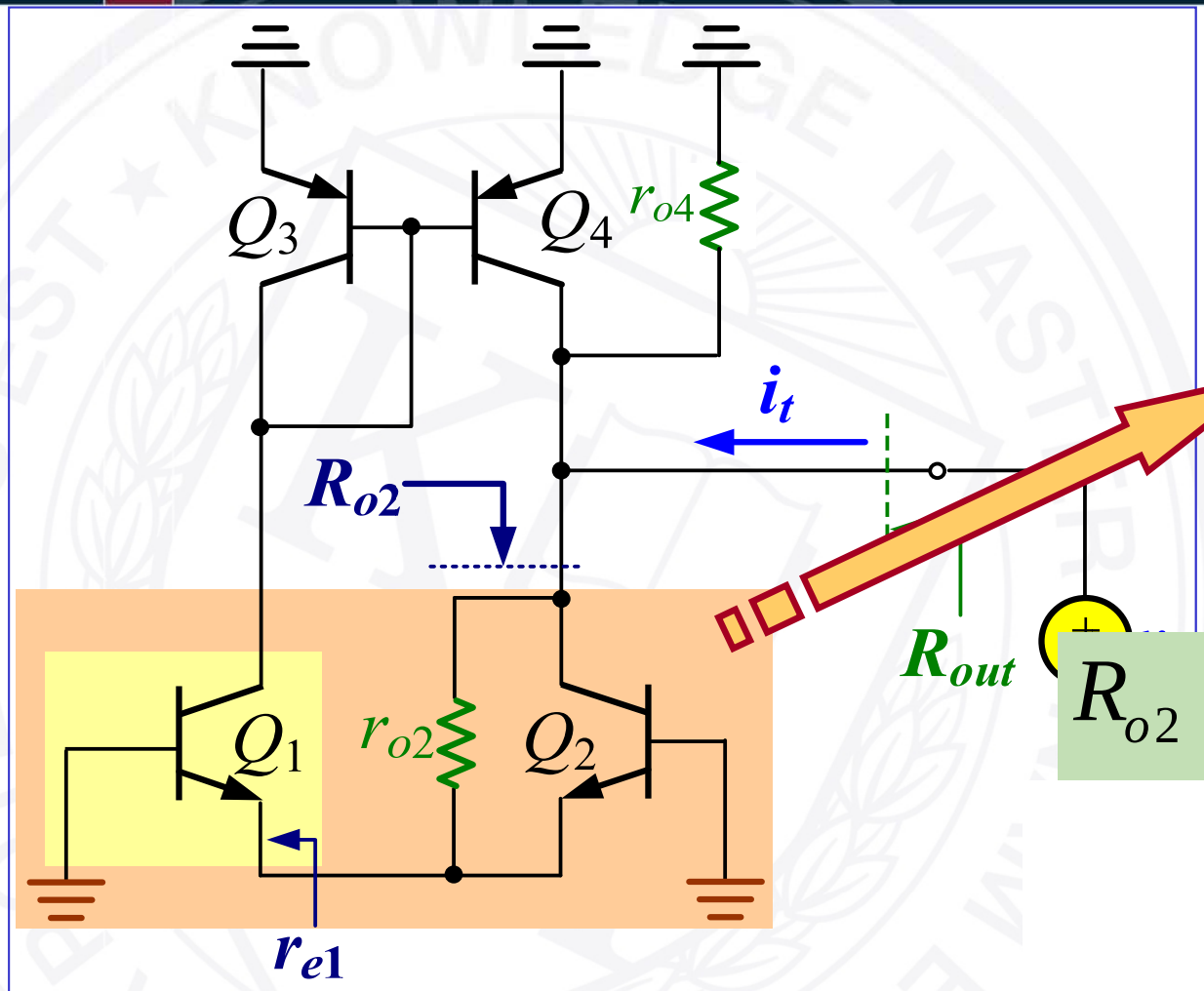
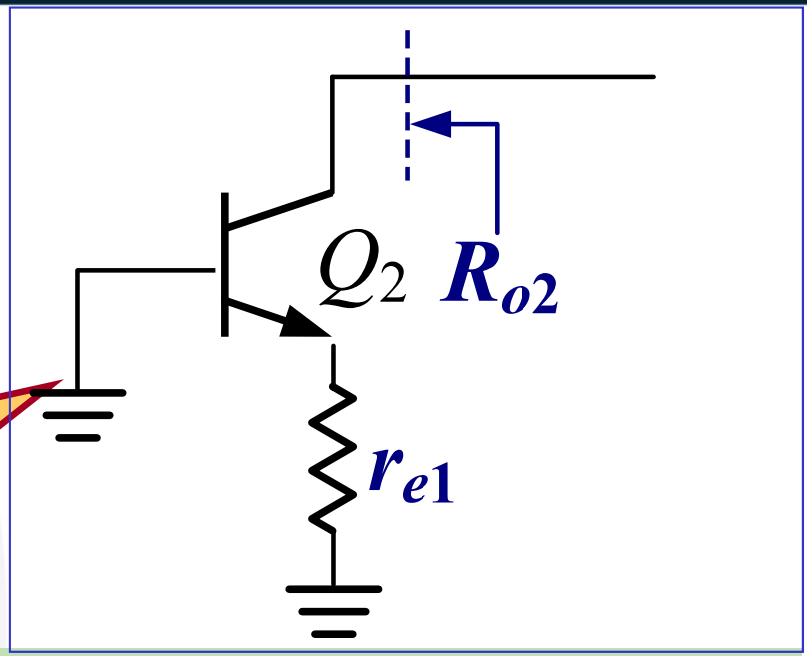
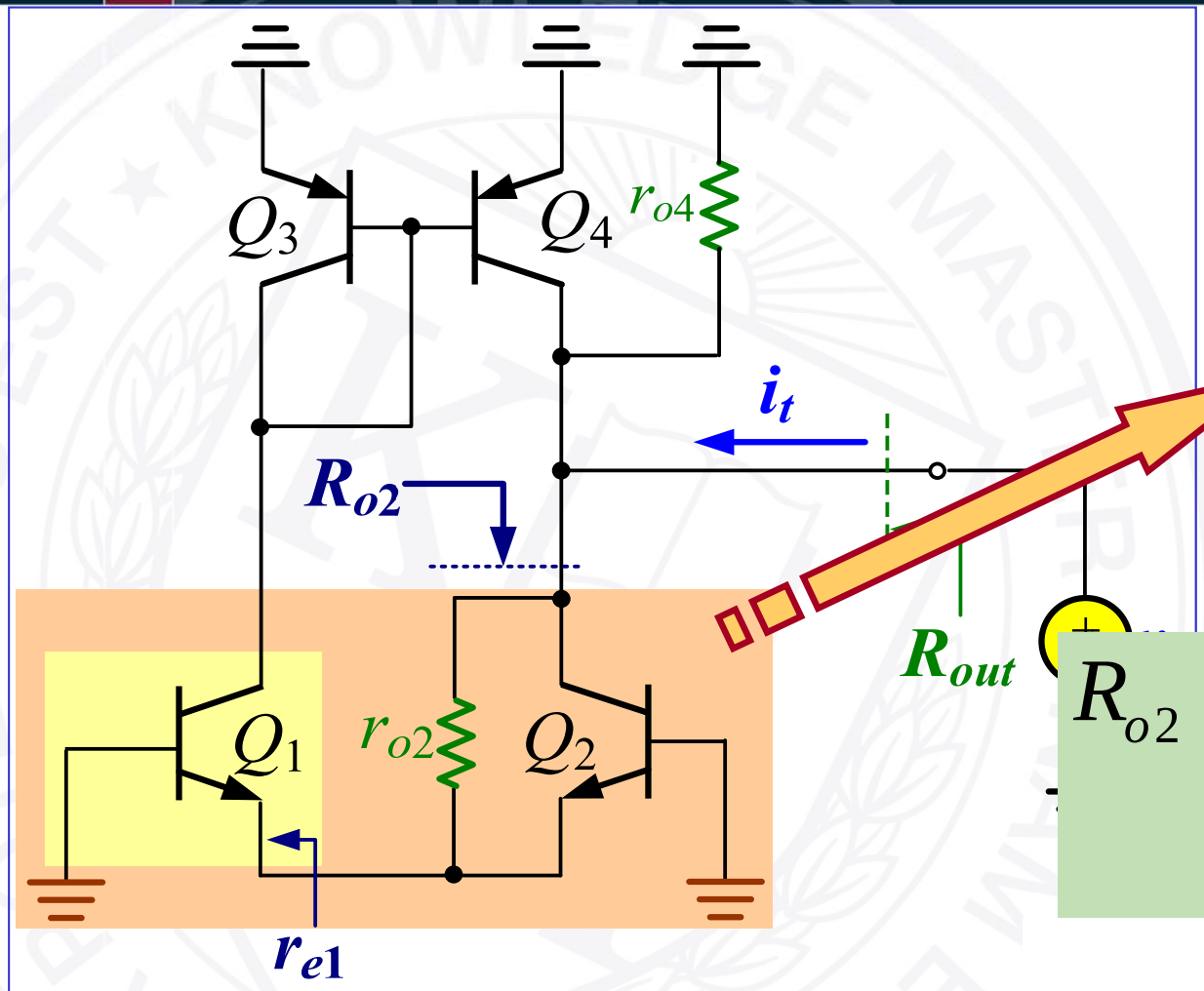
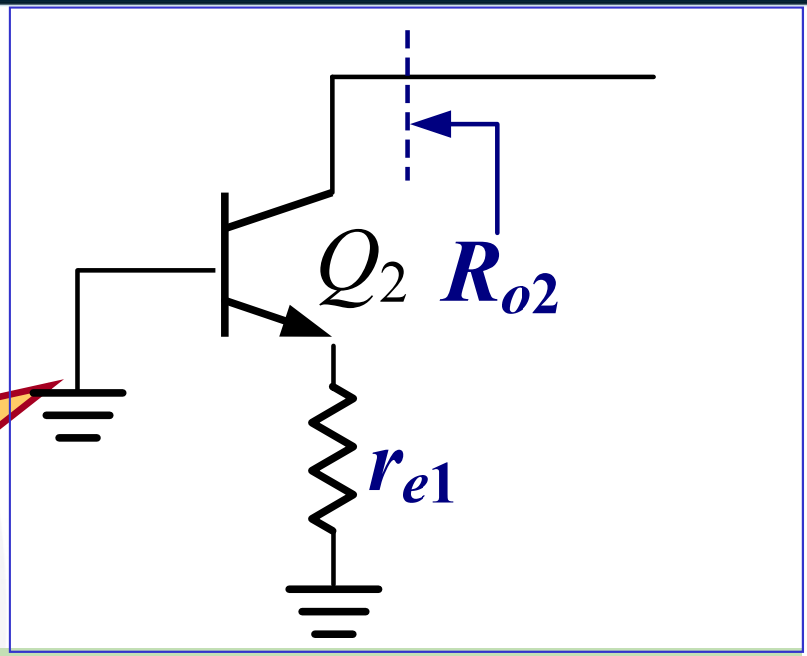




$$R_{o2} = r_{o2} + (1+\mu)(r_{\pi 2} \| r_{e1})$$

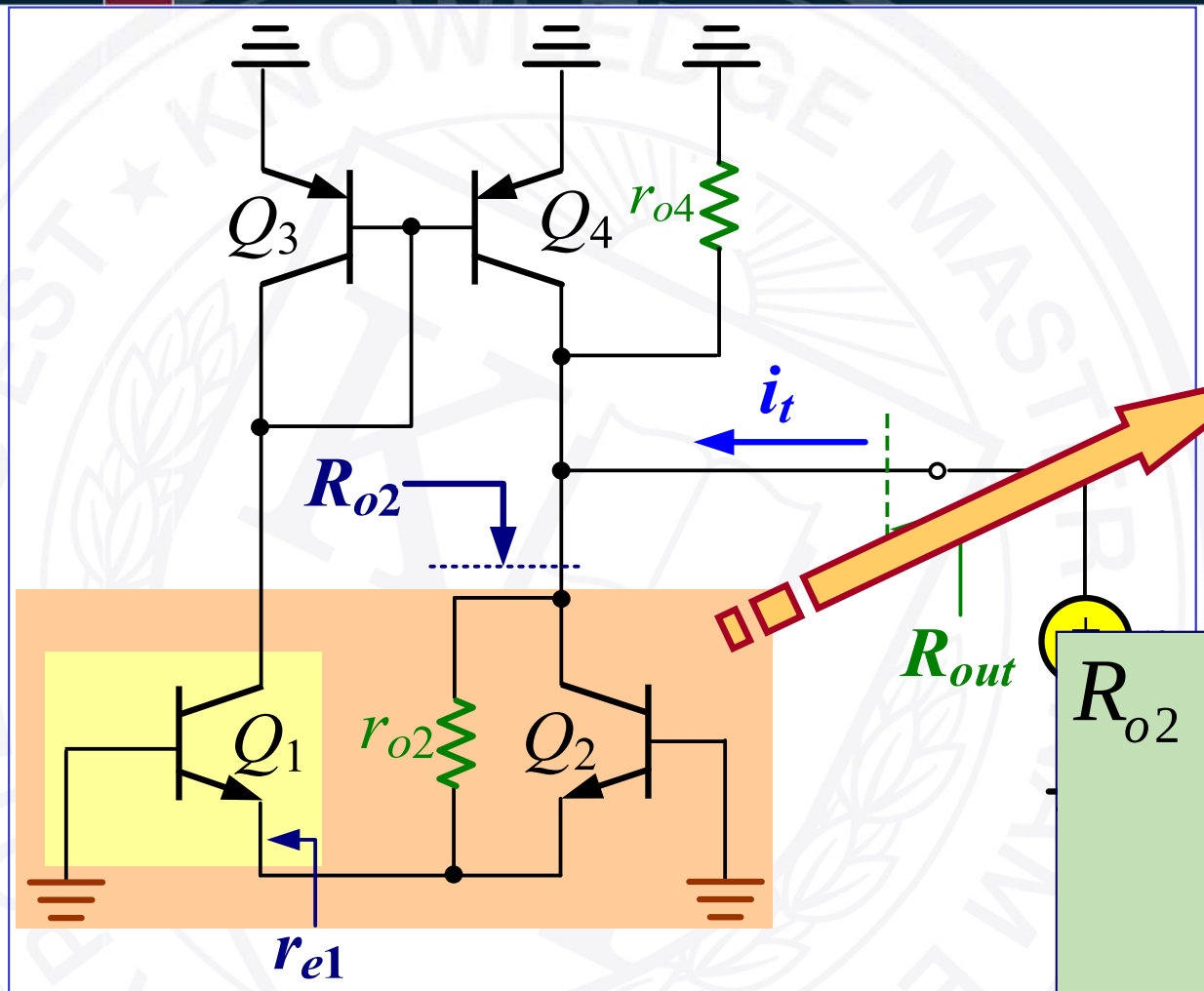
Output Resistance

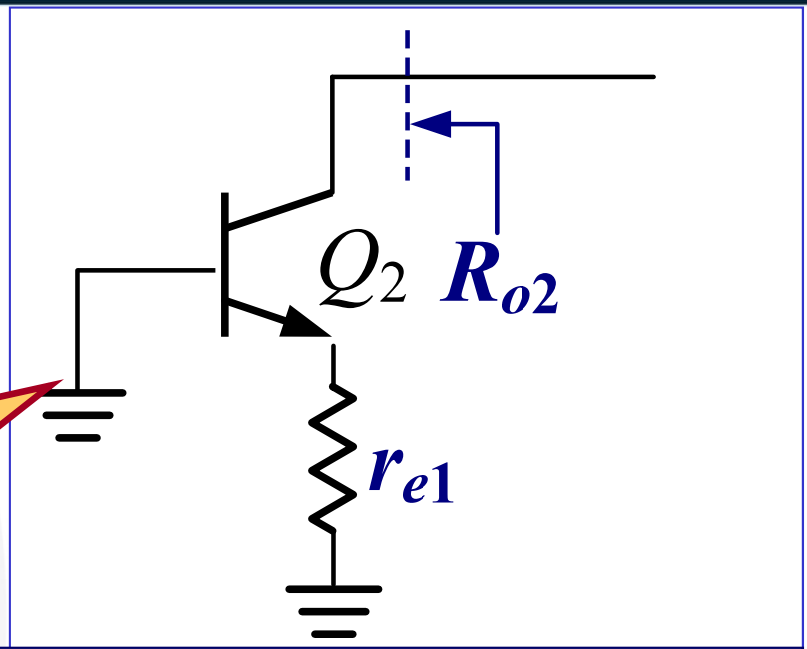




$$R_{o2} = r_{o2} + (1+\mu)(r_{\pi 2} \| r_{e1})$$
$$\cong r_{o2} + (1+g_{m2}r_{o2})r_{e1}$$

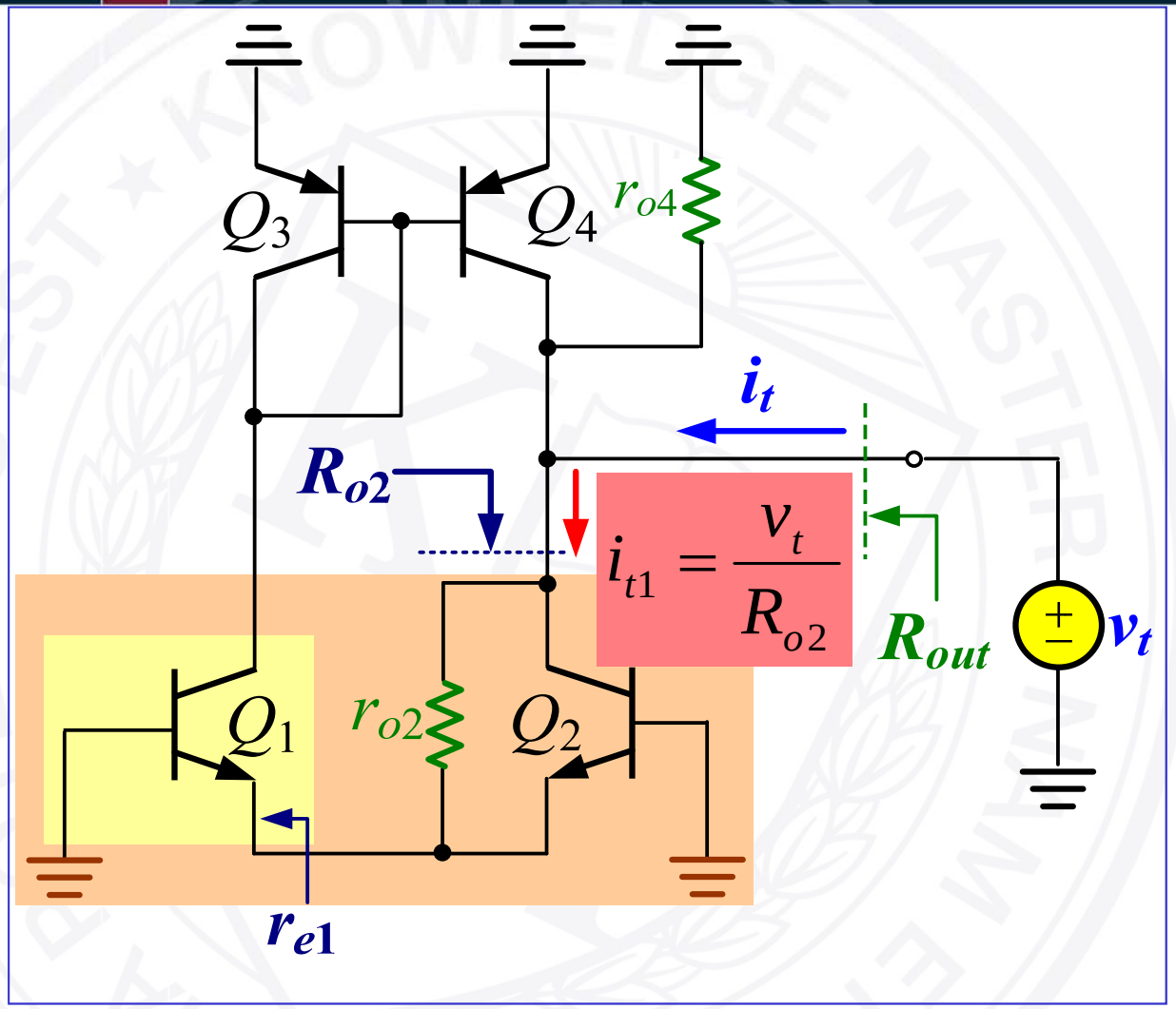
Output Resistance





$$R_{o2} = r_{o2} + (1+\mu)(r_{\pi 2} \| r_{e1})$$
$$\cong r_{o2} + (1+g_{m2}r_{o2})r_{e1}$$
$$\cong r_{o2} + \alpha r_{o2} \cong 2r_{o2}$$

Output Resistance



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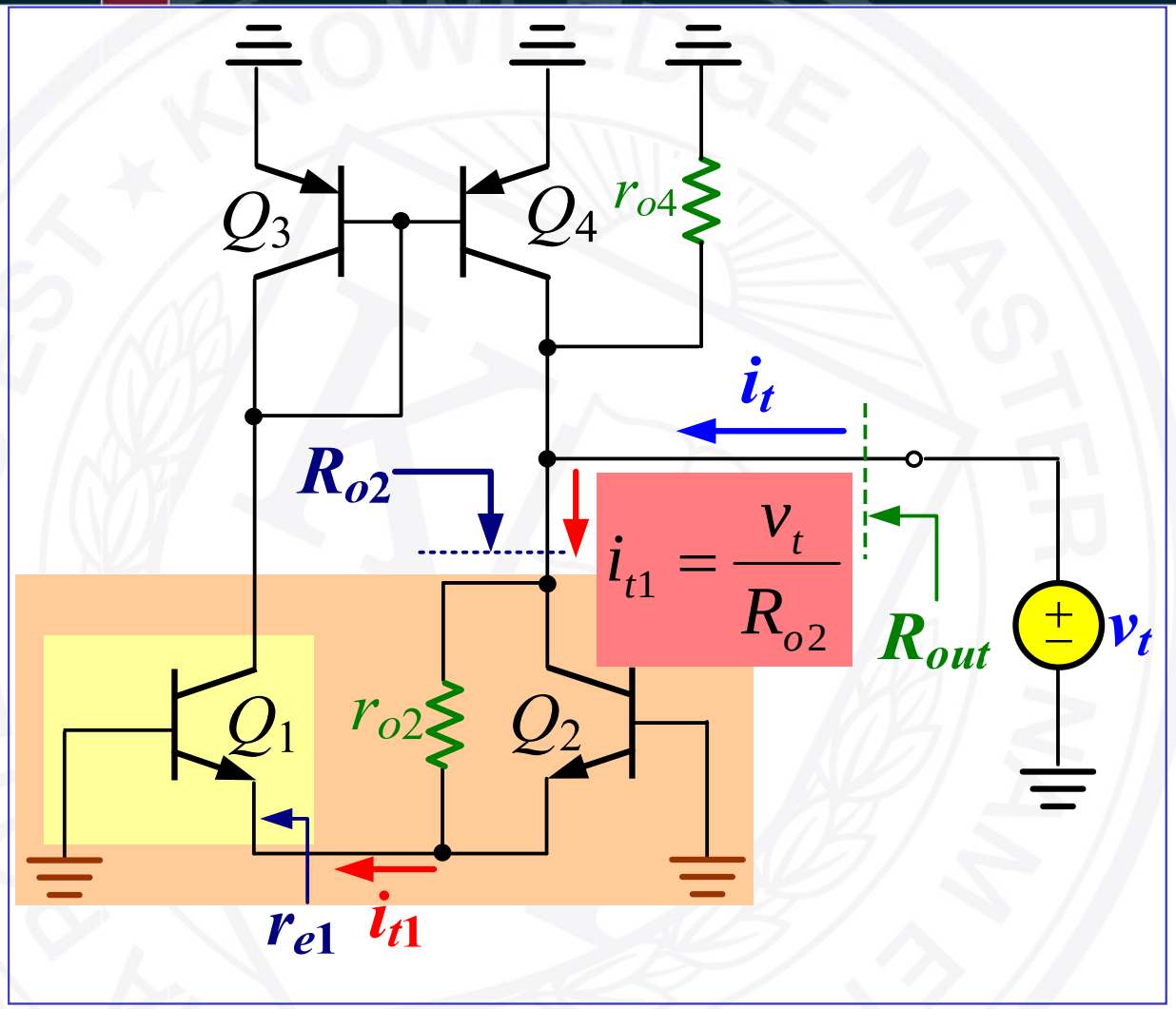

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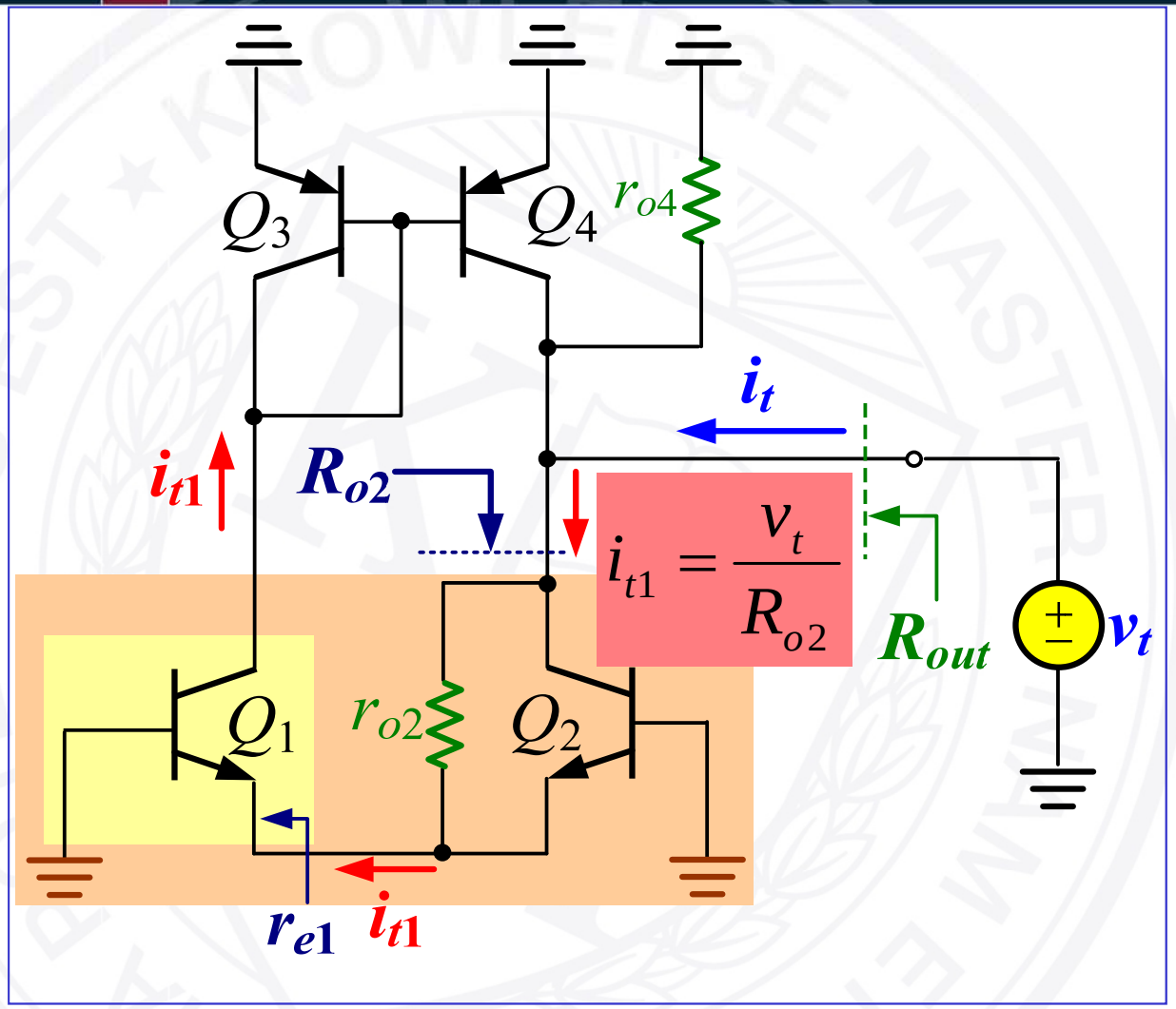

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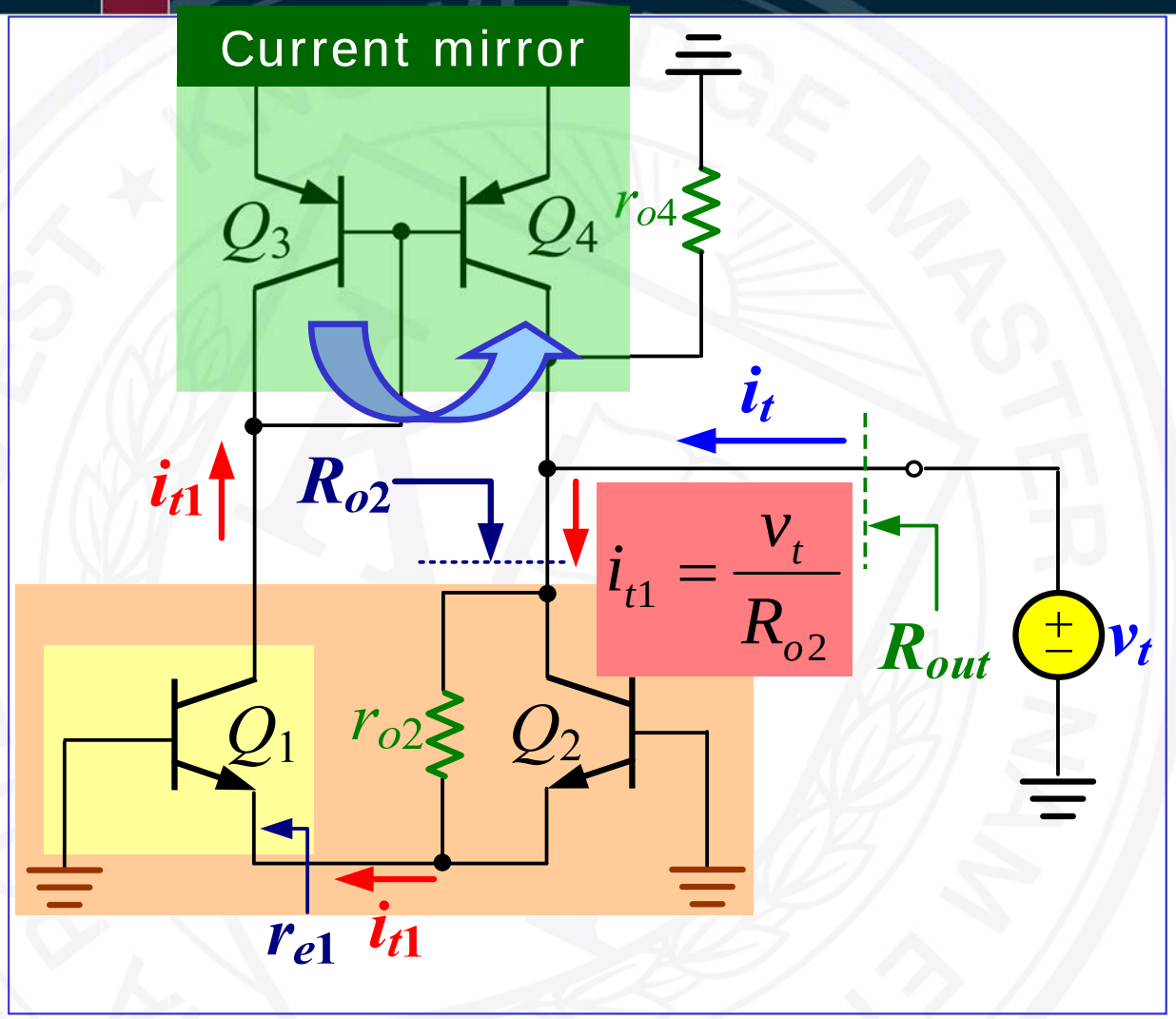

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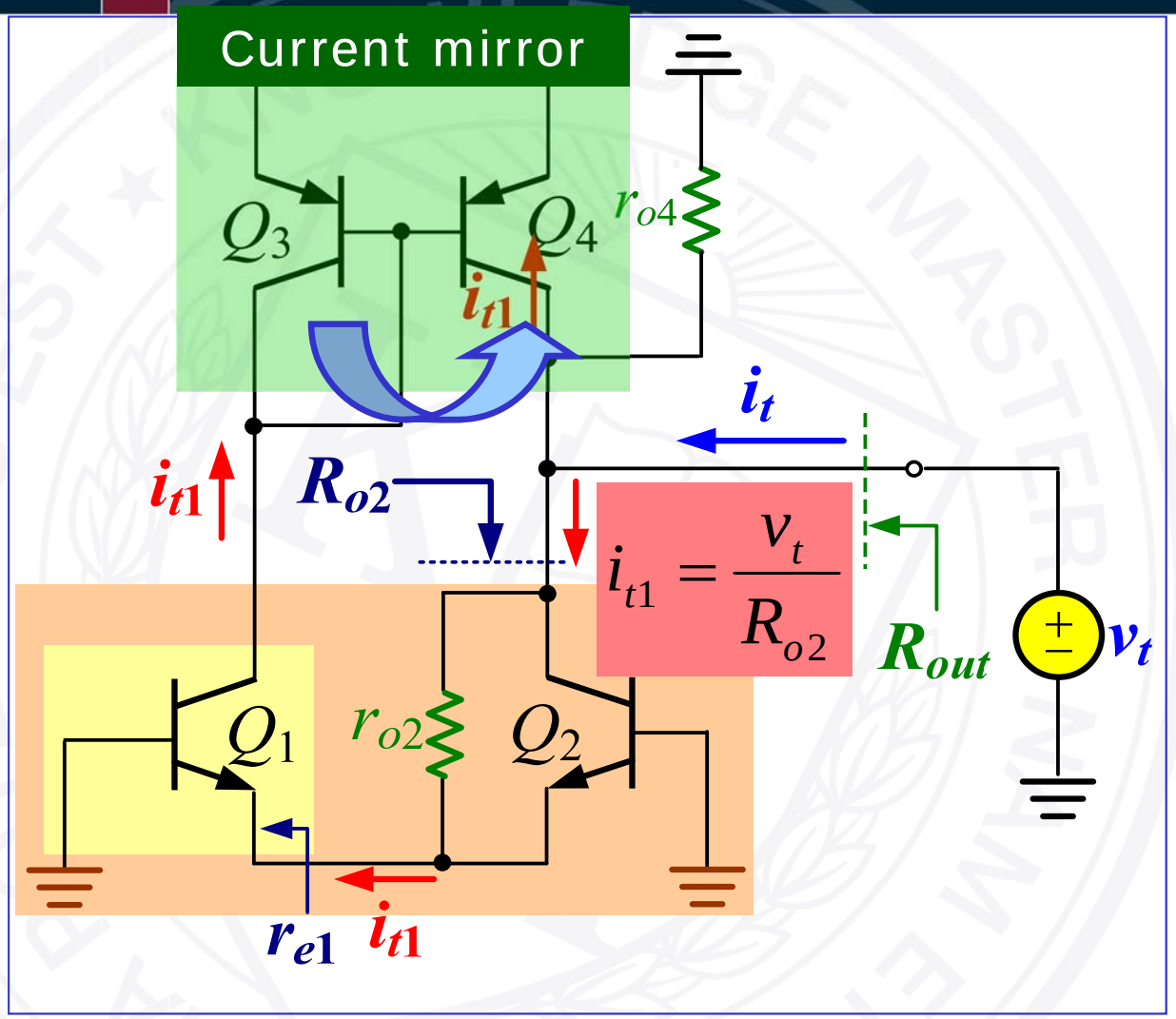
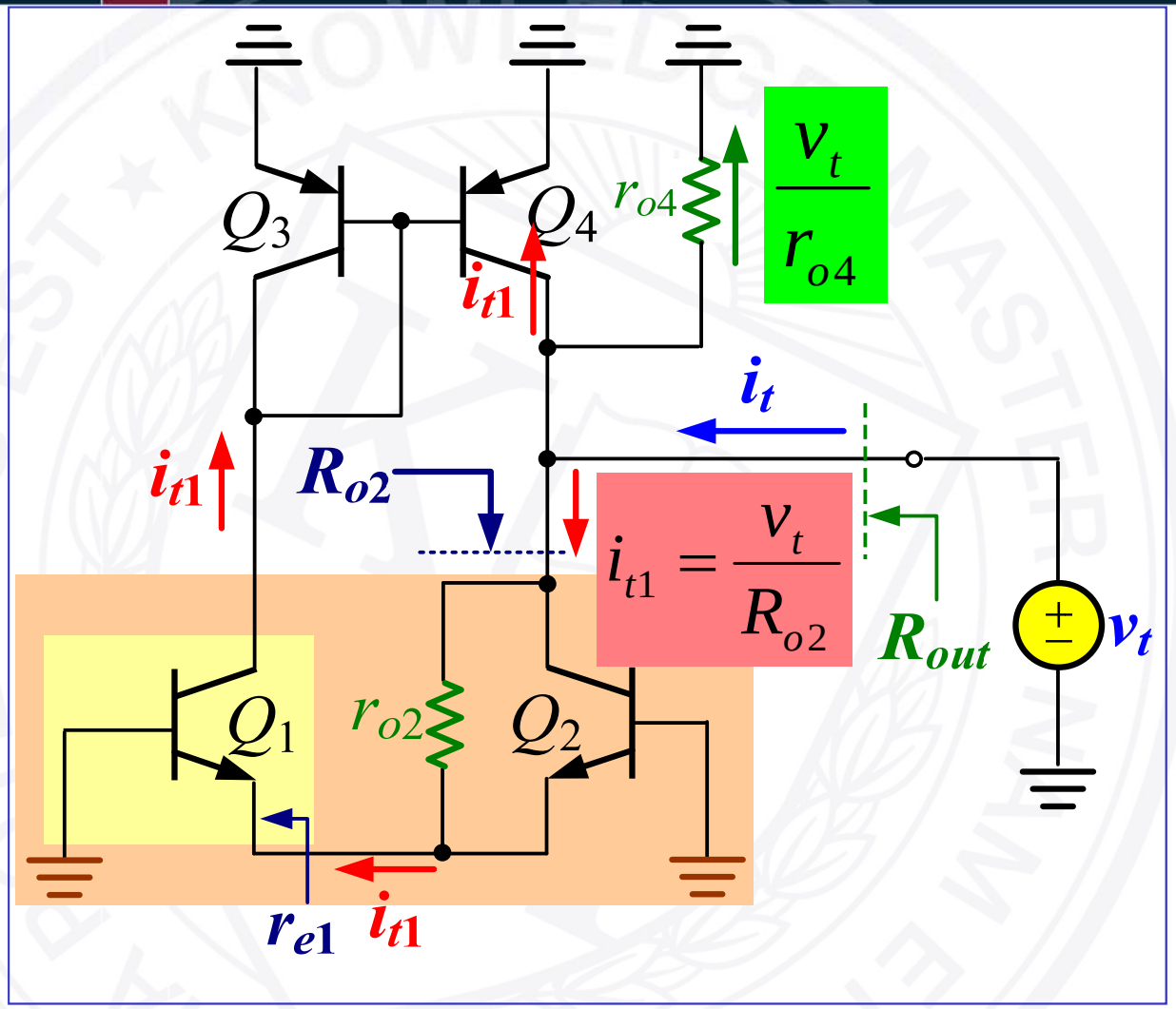
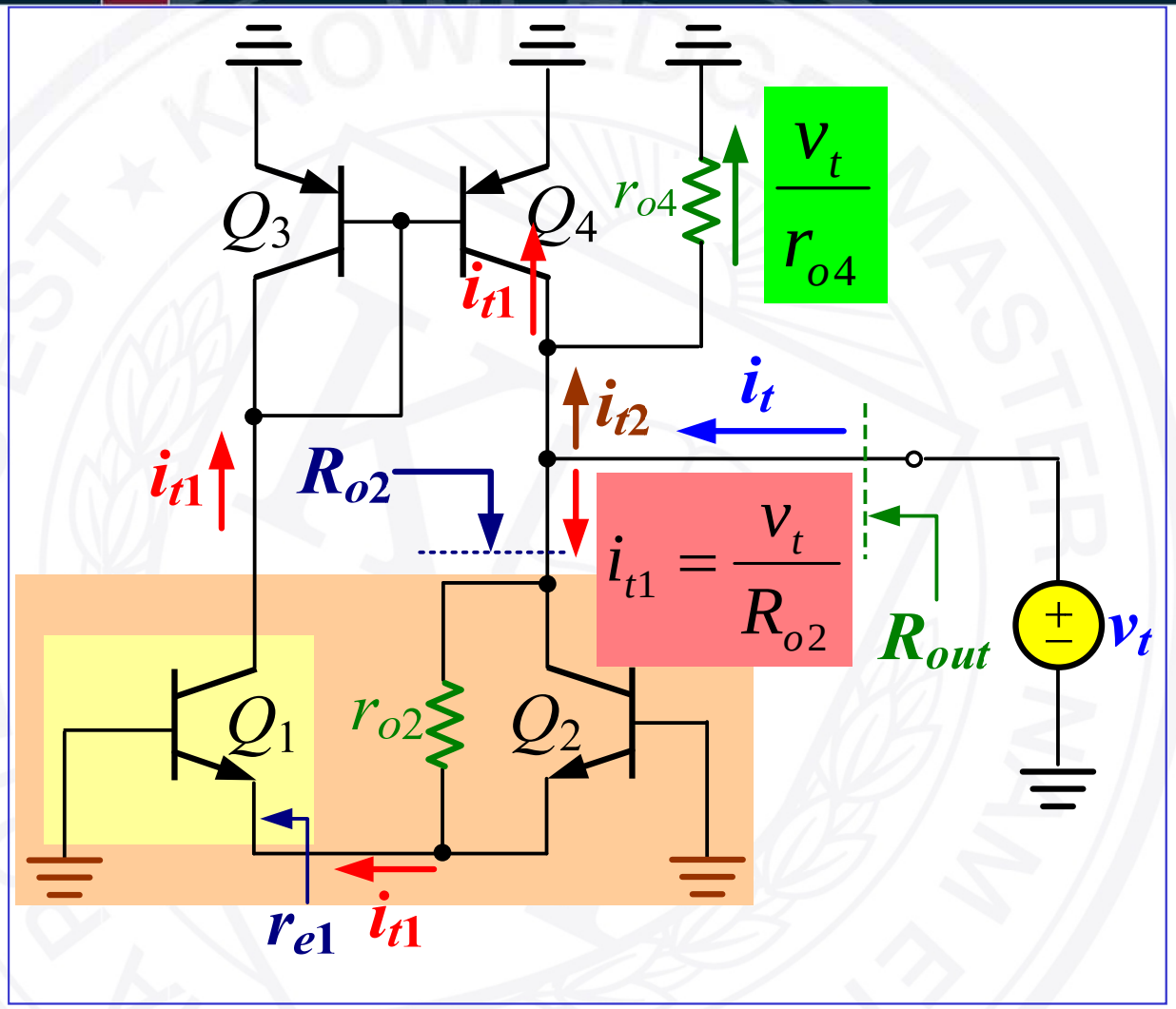


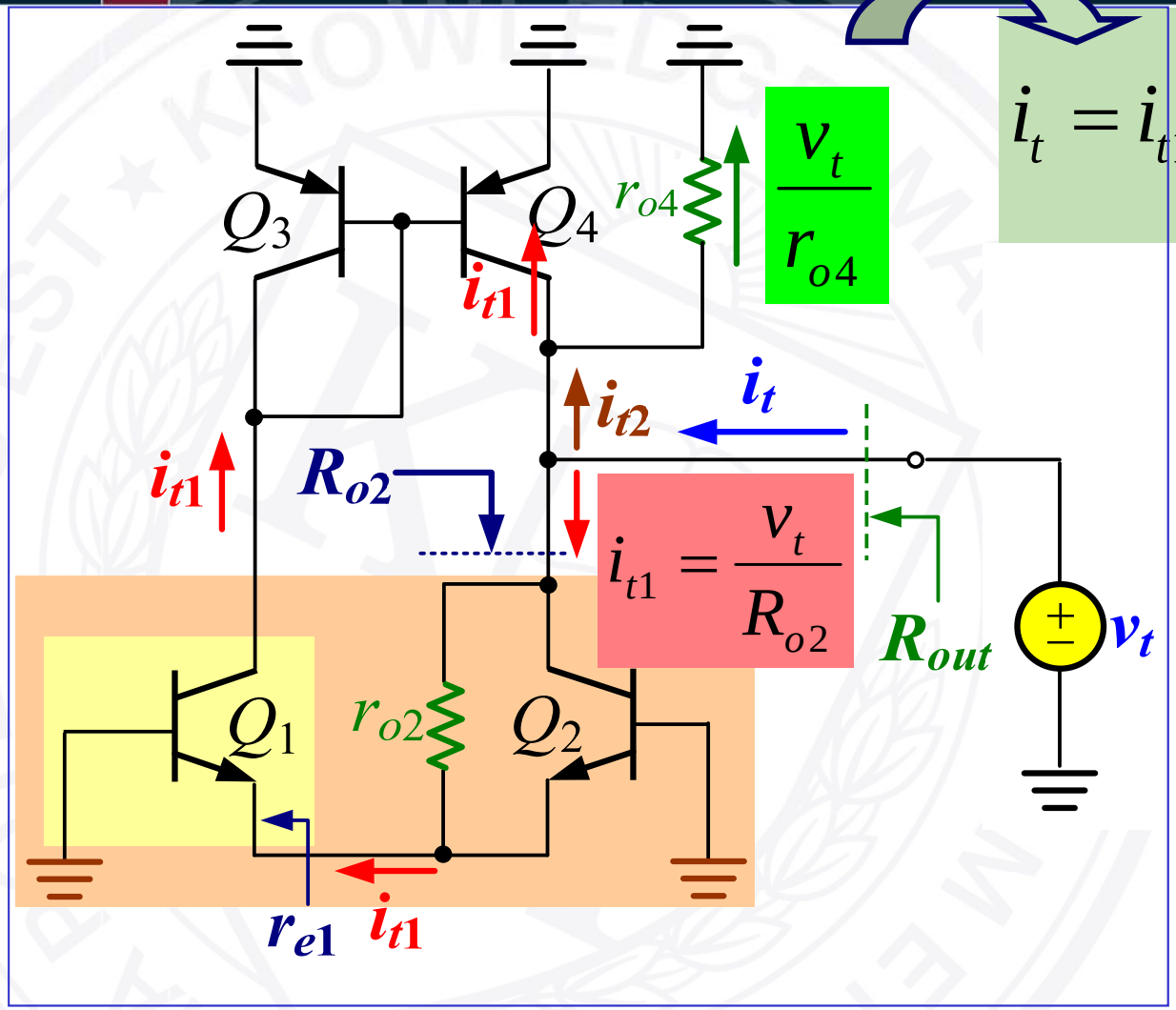
Output Resistance



Output Resistance



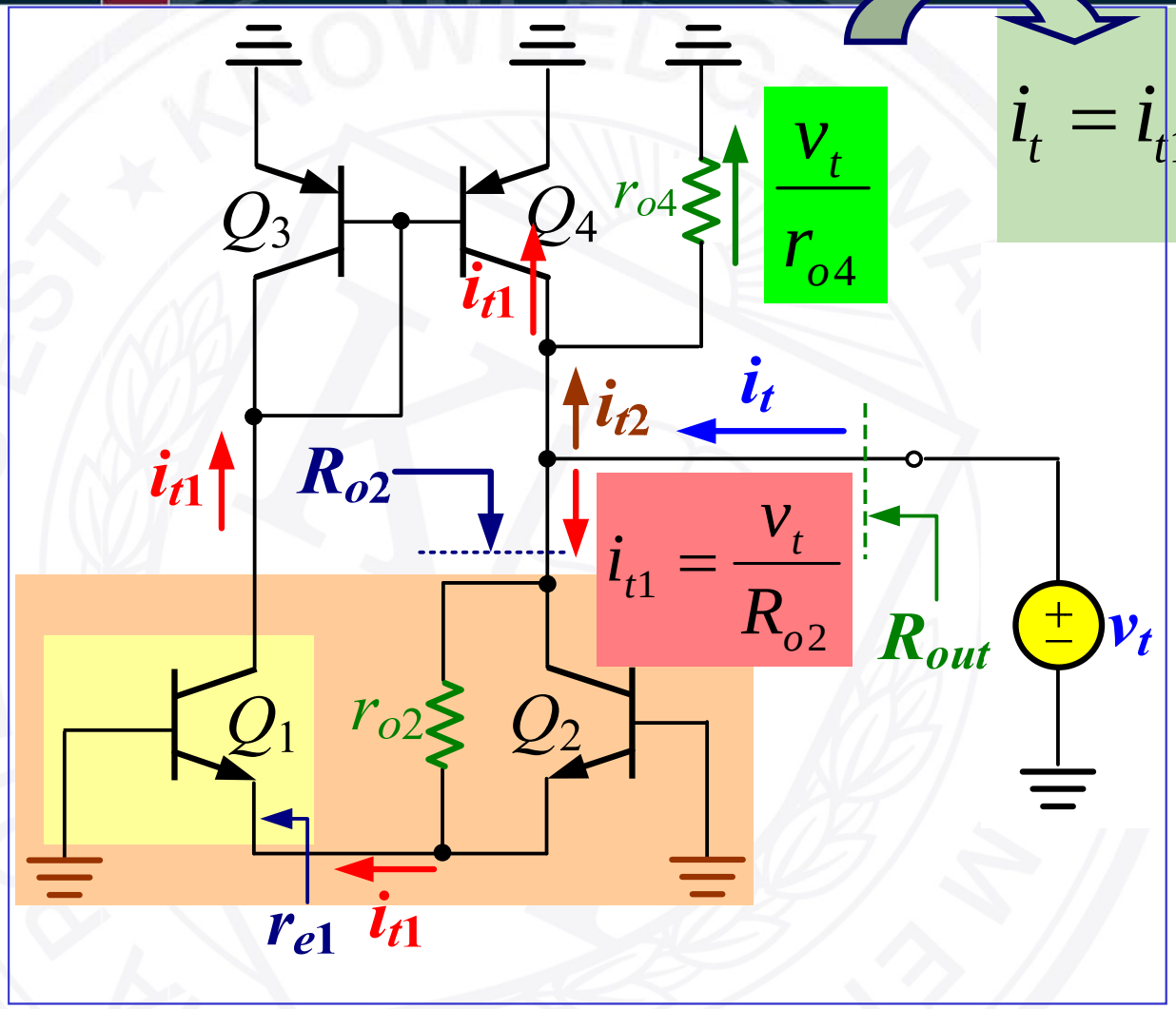
Output Resistance



$$i_t = i_{t1} + i_{t2}$$

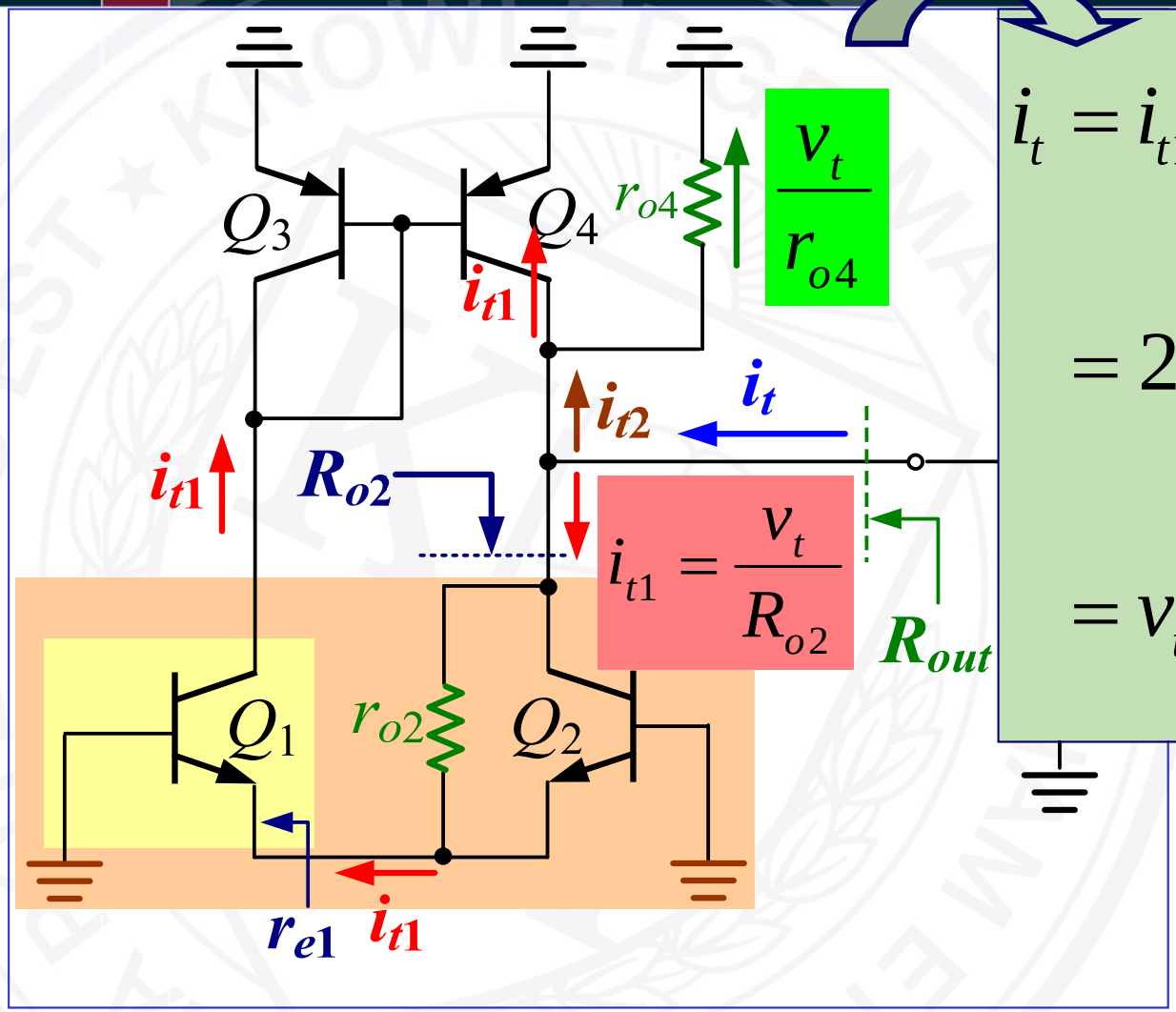
$$\frac{v_t}{r_{o4}}$$

Output Resistance



$$i_t = i_{t1} + i_{t2} = \frac{v_t}{R_{o2}} + \frac{v_t}{R_{o2}} + \frac{v_t}{r_{o4}}$$

Output Resistance

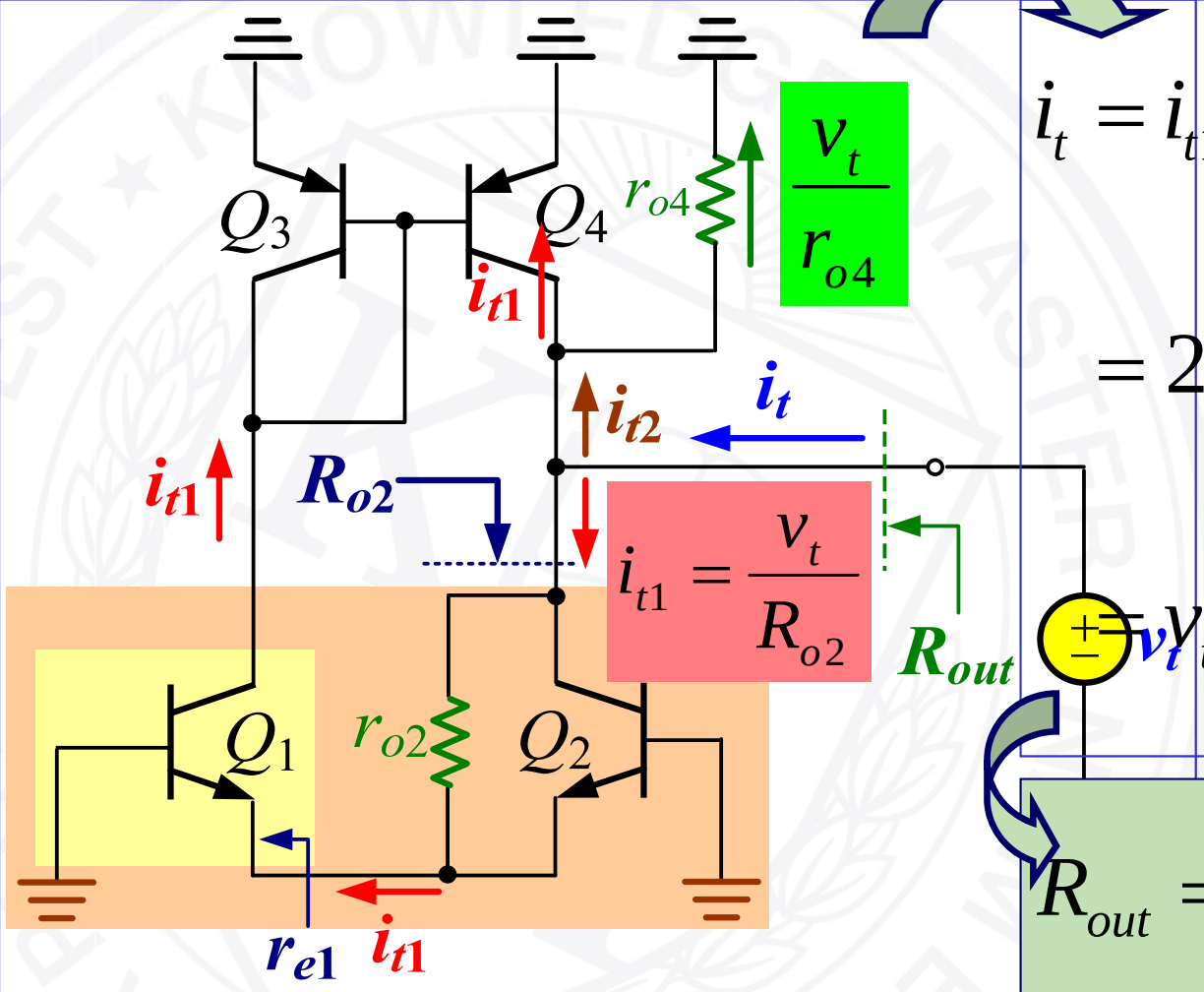


$$i_t = i_{t1} + i_{t2} = \frac{v_t}{R_{o2}} + \frac{v_t}{R_{o2}} + \frac{v_t}{r_{o4}}$$

$$= 2\frac{v_t}{R_{o2}} + \frac{v_t}{r_{o4}} = 2\frac{v_t}{2r_{o2}} + \frac{v_t}{r_{o4}}$$

$$= v_t\left(\frac{1}{r_{o2}} + \frac{1}{r_{o4}}\right)$$

Output Resistance



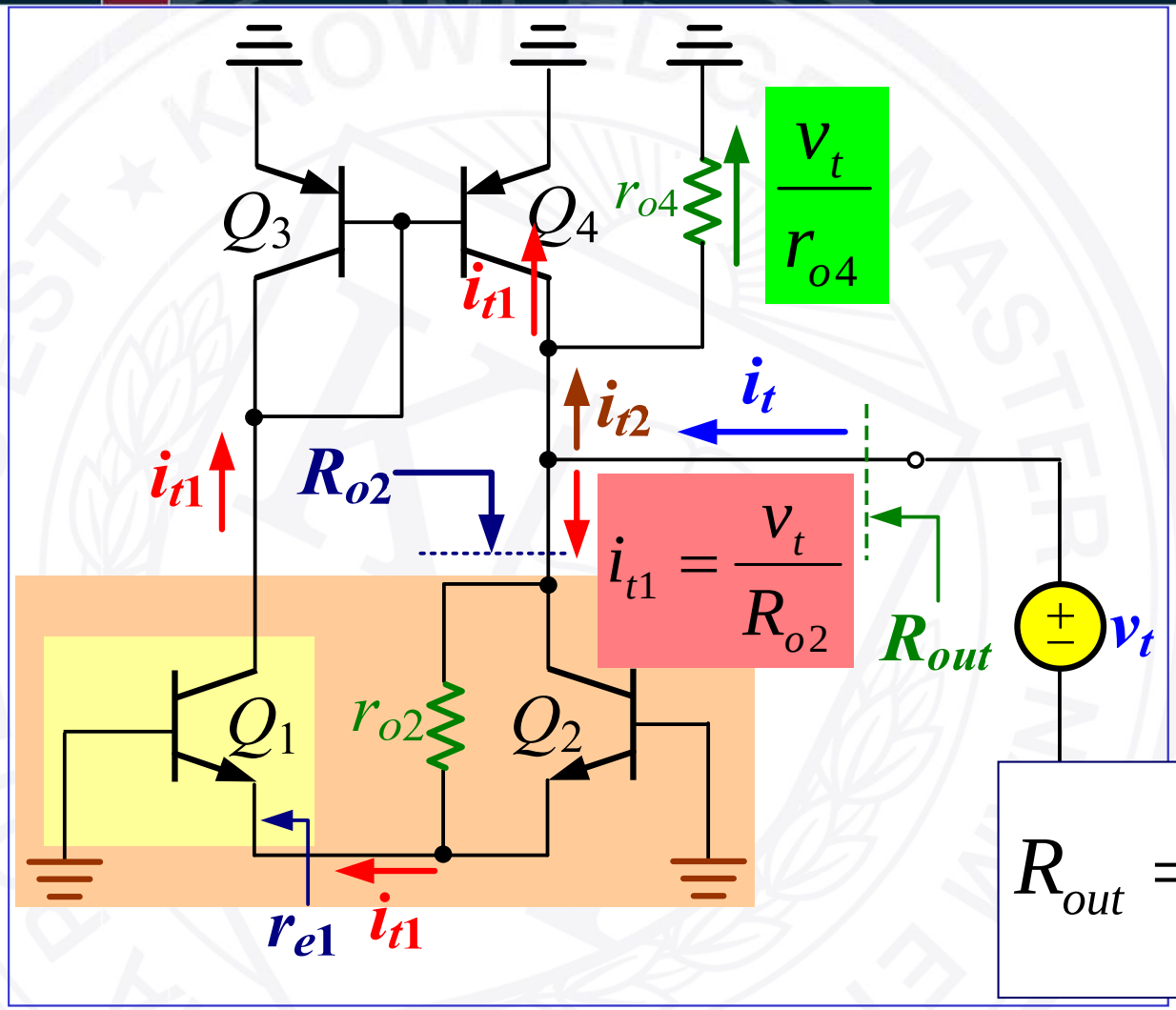
$$i_t = i_{t1} + i_{t2} = \frac{v_t}{R_{o2}} + \frac{v_t}{R_{o2}} + \frac{v_t}{r_{o4}}$$

$$= 2\frac{v_t}{R_{o2}} + \frac{v_t}{r_{o4}} = 2\frac{v_t}{2r_{o2}} + \frac{v_t}{r_{o4}}$$

$$= v_t\left(\frac{1}{r_{o2}} + \frac{1}{r_{o4}}\right)$$

$$R_{out} = (i_t / v_t)^{-1} = \left(\frac{1}{r_{o2}} + \frac{1}{r_{o4}}\right)^{-1}$$

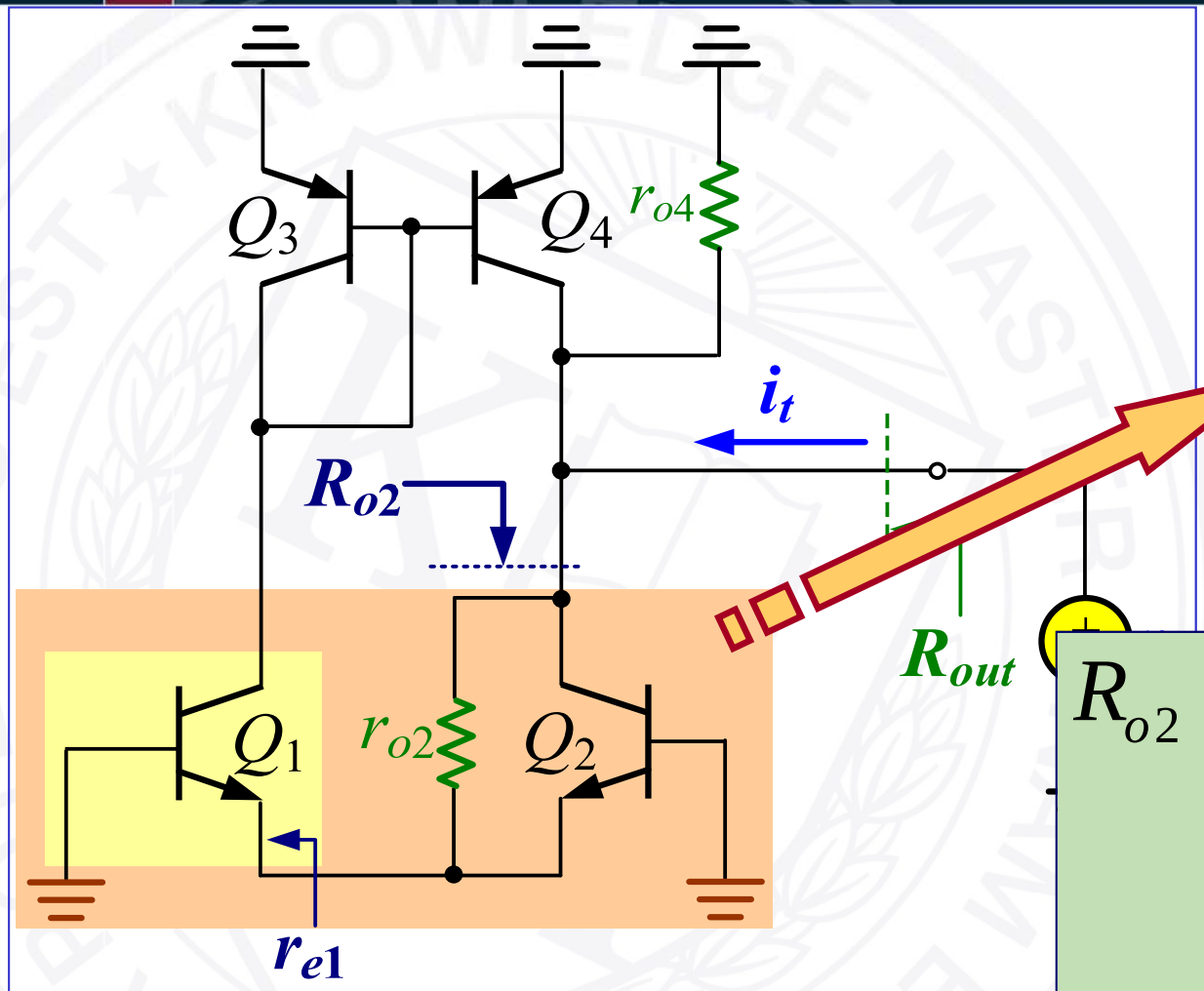
Output Resistance

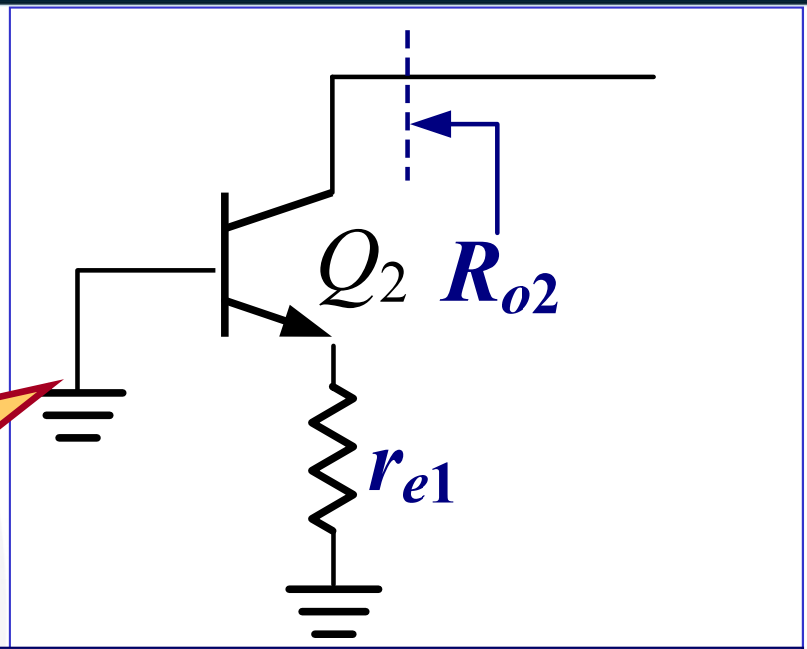


$$R_{out} = r_{o2} \parallel r_{o4}$$

$$R_{out} = (i_t / v_t)^{-1} = \left(\frac{1}{r_{o2}} + \frac{1}{r_{o4}}\right)^{-1}$$

Output Resistance





$$R_{o2} = r_{o2} + (1+\mu)(r_{\pi 2} \| r_{e1})$$
$$\cong r_{o2} + (1+g_{m2}r_{o2})r_{e1}$$
$$\cong r_{o2} + \alpha r_{o2} \cong 2r_{o2}$$

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