



Lecture

CMOS & BiCMOS IC Amplifiers

Vincent Chang

Outline

CMOS amplifiers

- CMOS CS amp
- CMOS source follower

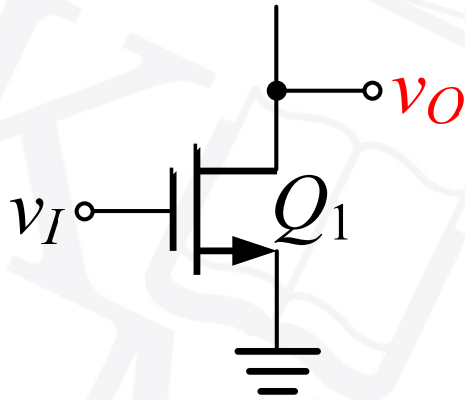
BiCMOS cascode

- Finesse
- Analysis-by-inspection

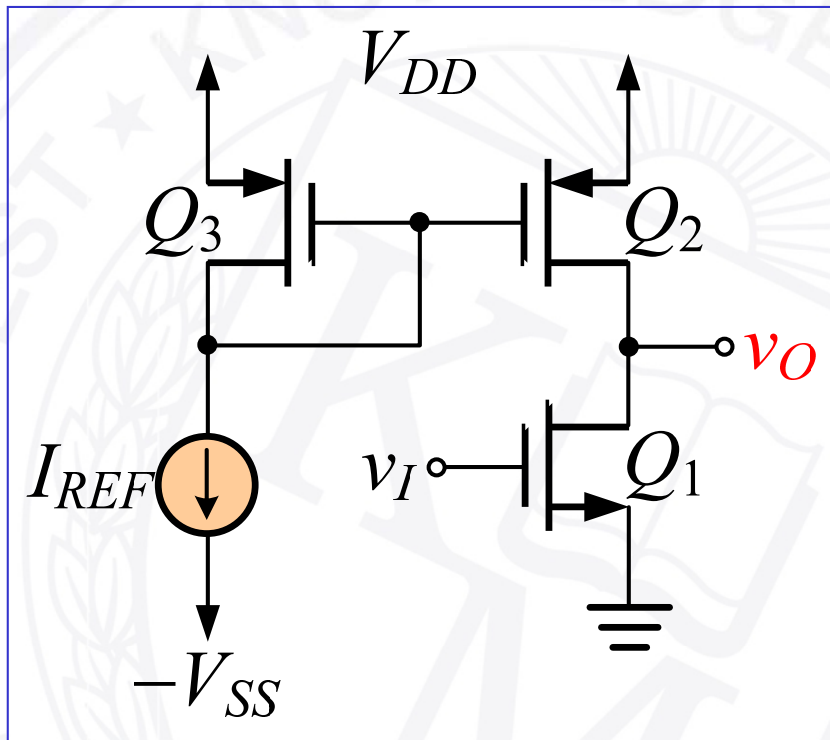
BiCMOS double cascode

- Finesse
- Analysis-by-inspection

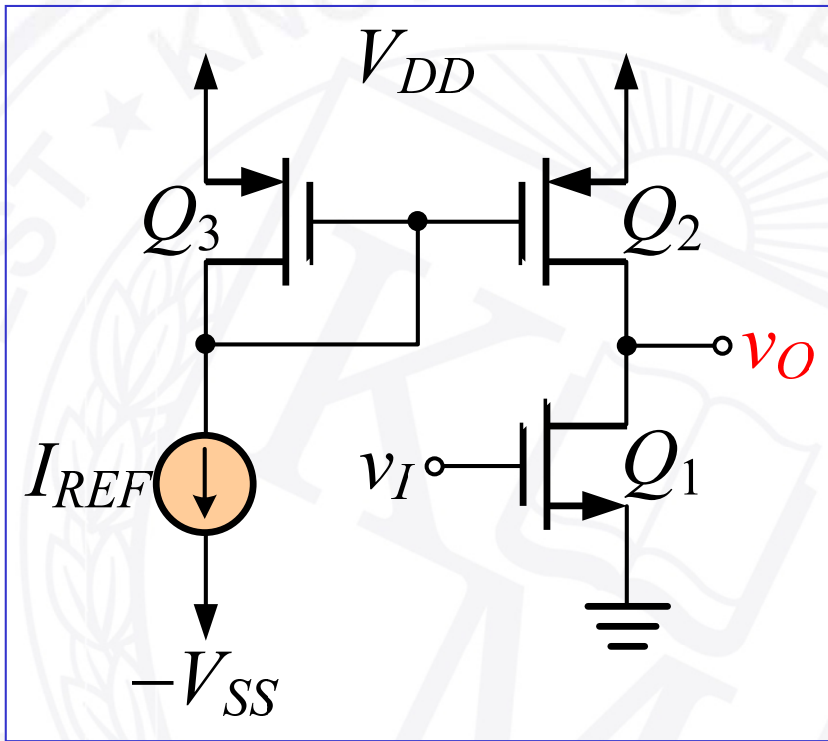
CMOS CS Amplifier



CMOS CS Amplifier

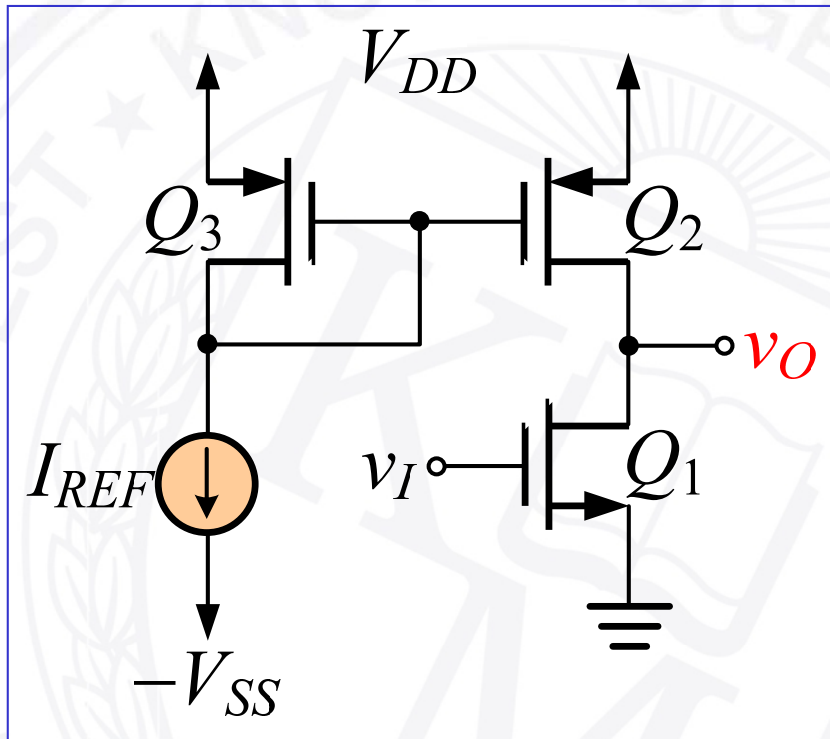


CMOS CS Amplifier—Assumption



Q1 & Q2: Saturation

CMOS CS Amplifier

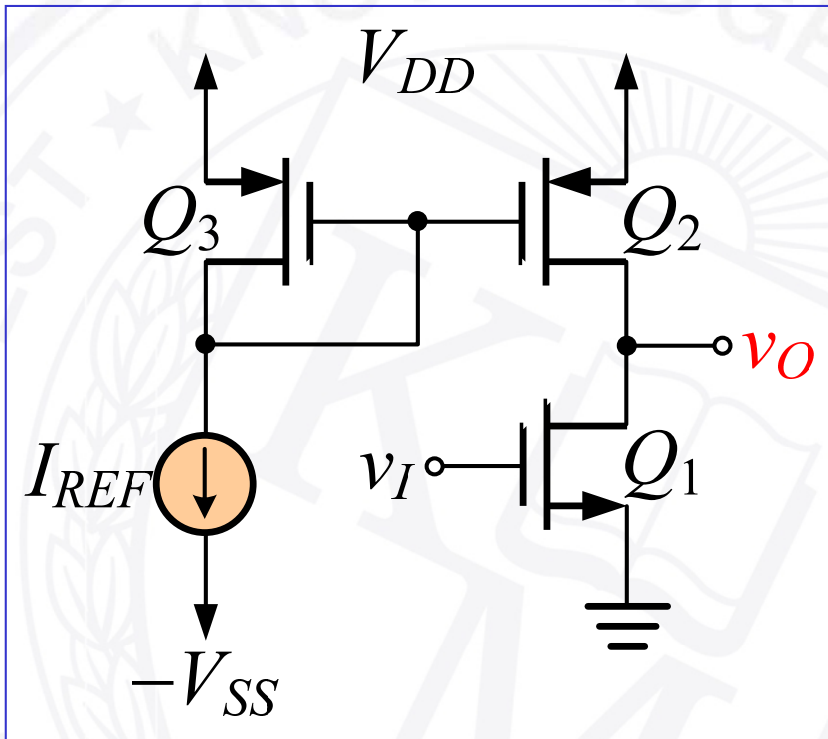


Q1 & Q2: Saturation

$$A_V \triangleq \frac{\Delta v_o}{\Delta v_i} =$$



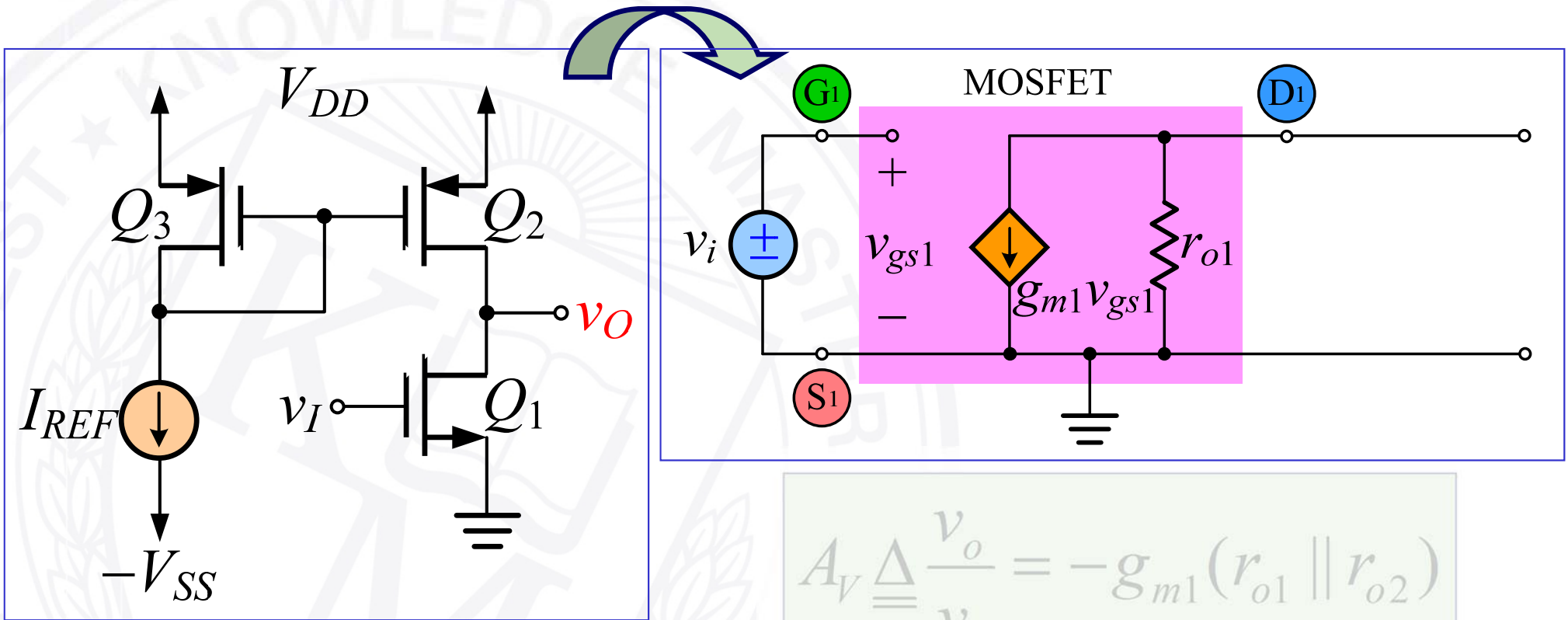
Analysis-by-Inspection



Q1 & Q2: Saturation

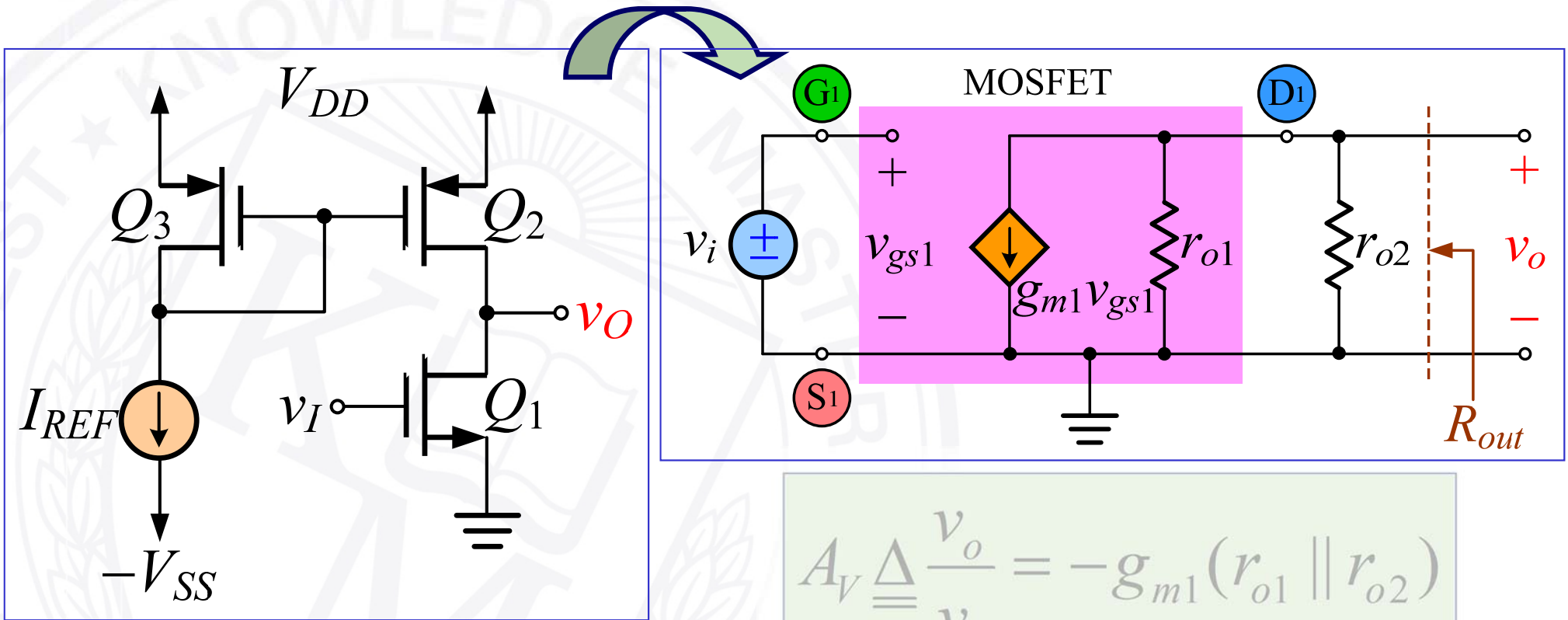
$$A_V \triangleq \frac{v_o}{v_i} = -g_{m1}(r_{o1} \parallel r_{o2})$$

Equivalent Circuit



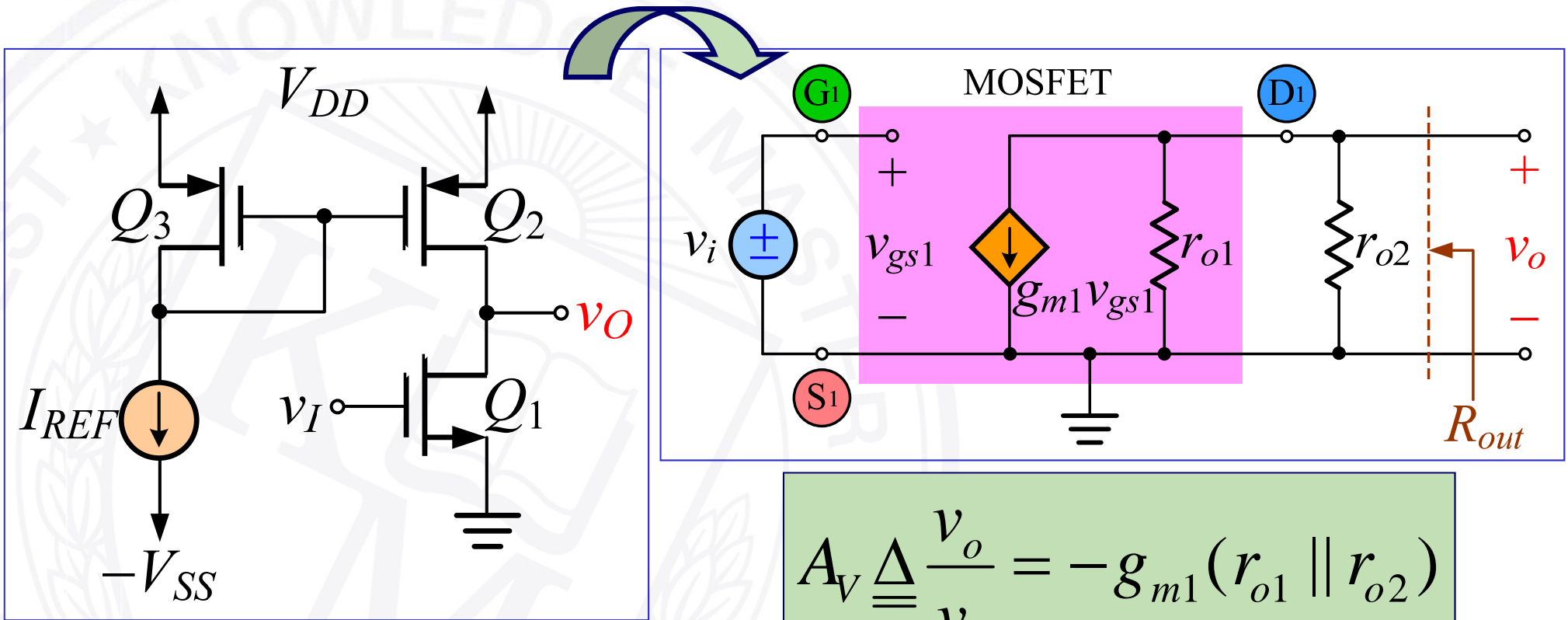
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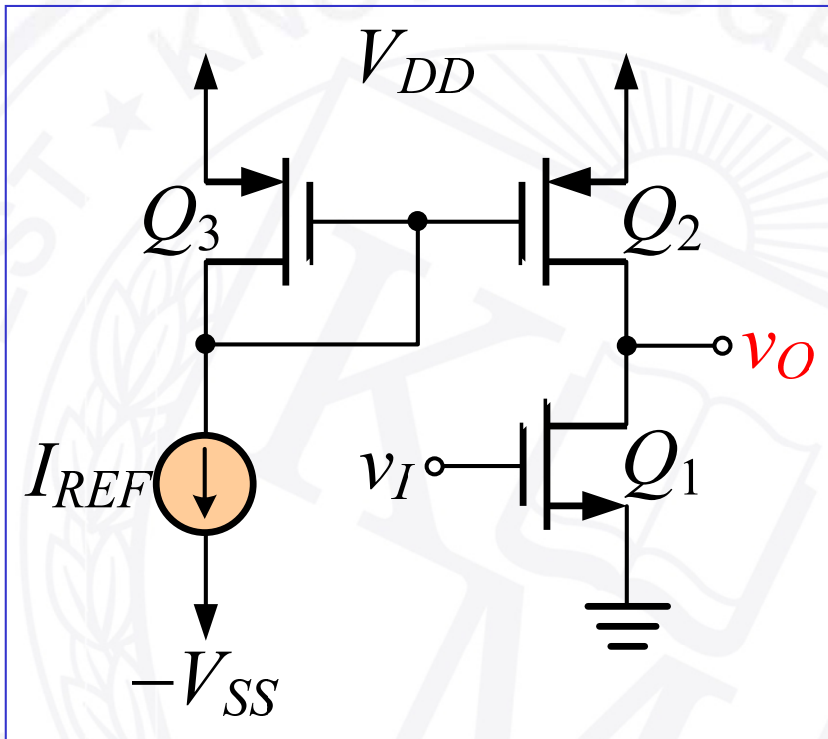
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CMOS CS Amplifier



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CMOS CS Amplifier

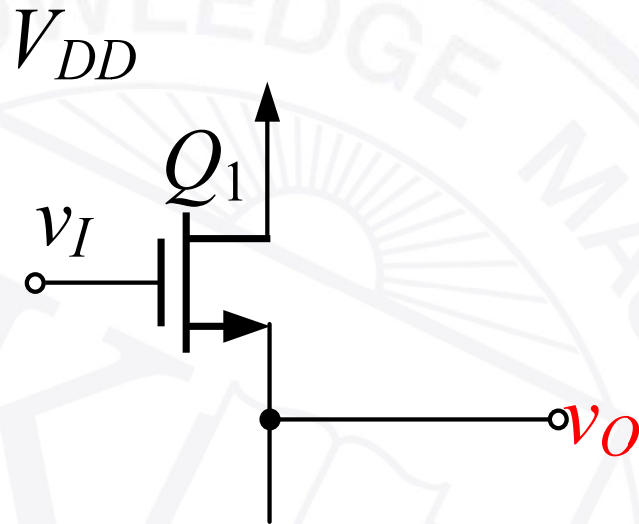


$$g_{m1} = \sqrt{2k_n I_{REF}}$$

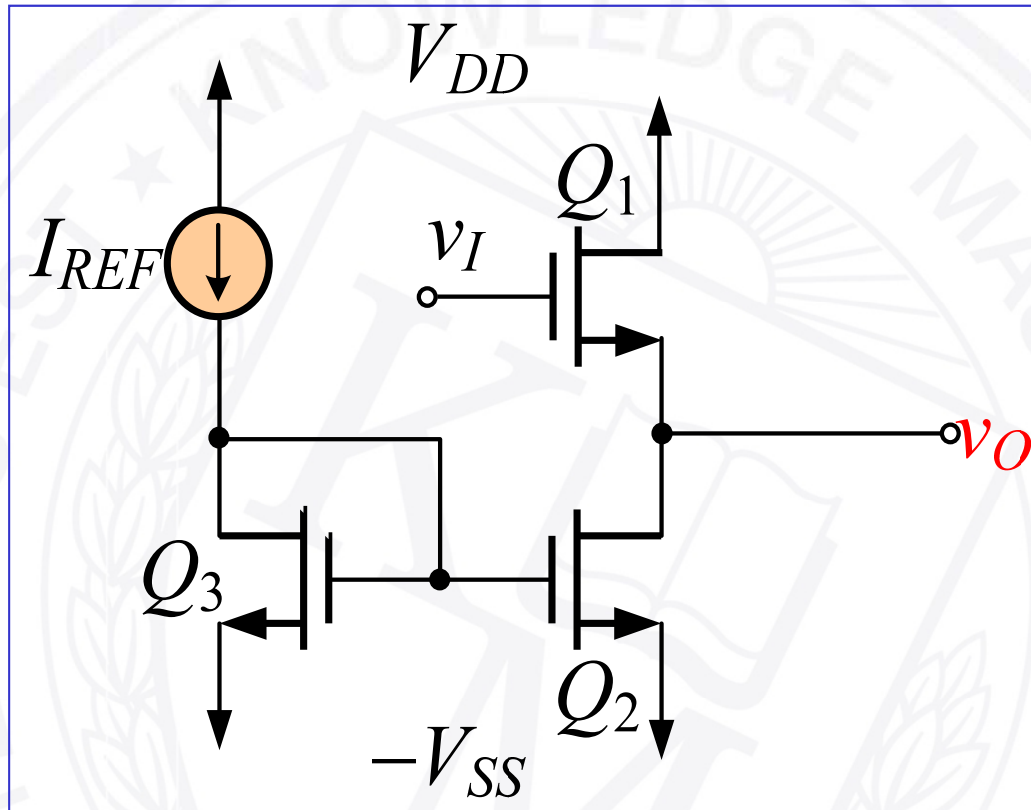
$$r_{o1} = r_{o2} = \frac{|V_A|}{I_{REF}}$$

$$A_V \triangleq \frac{v_o}{v_i} = -g_{m1} (r_{o1} \parallel r_{o2})$$

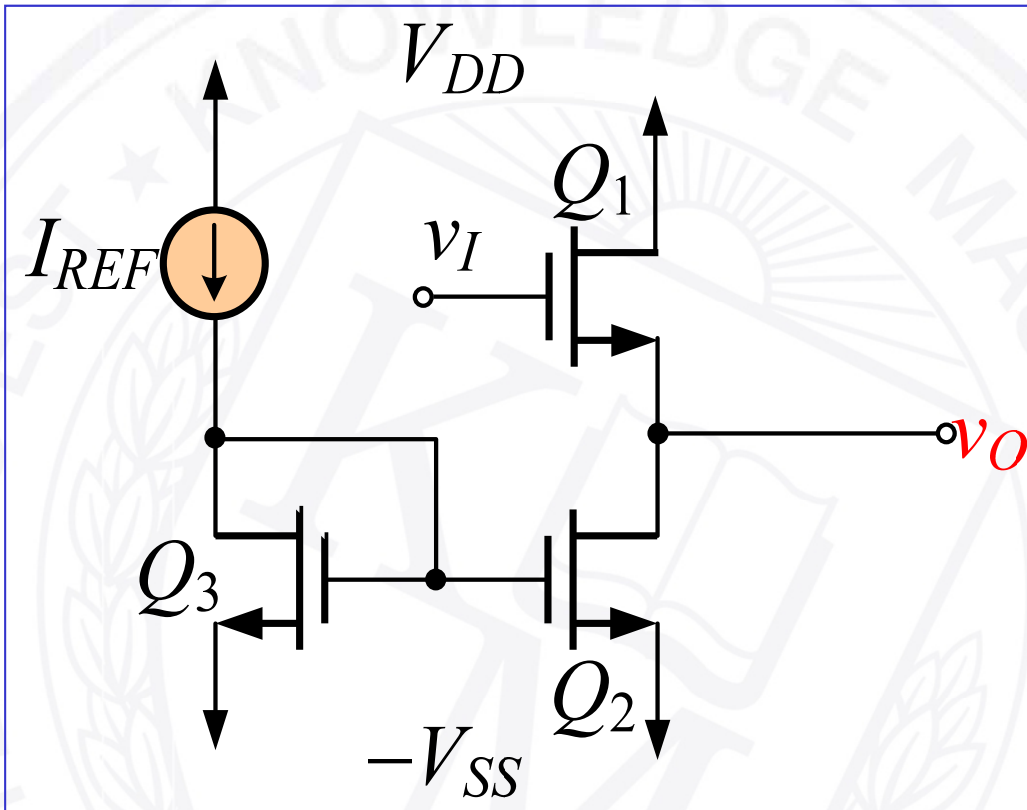
CMOS Source Follower



CMOS Source Follower

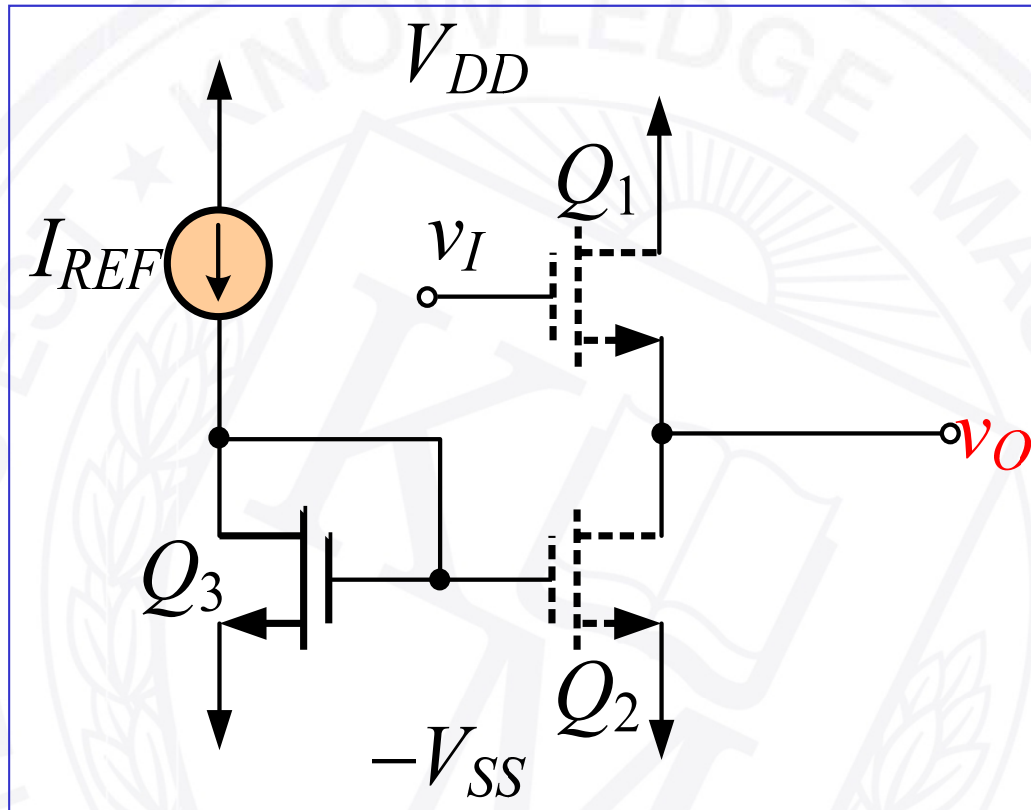


Assumption: Operating Point

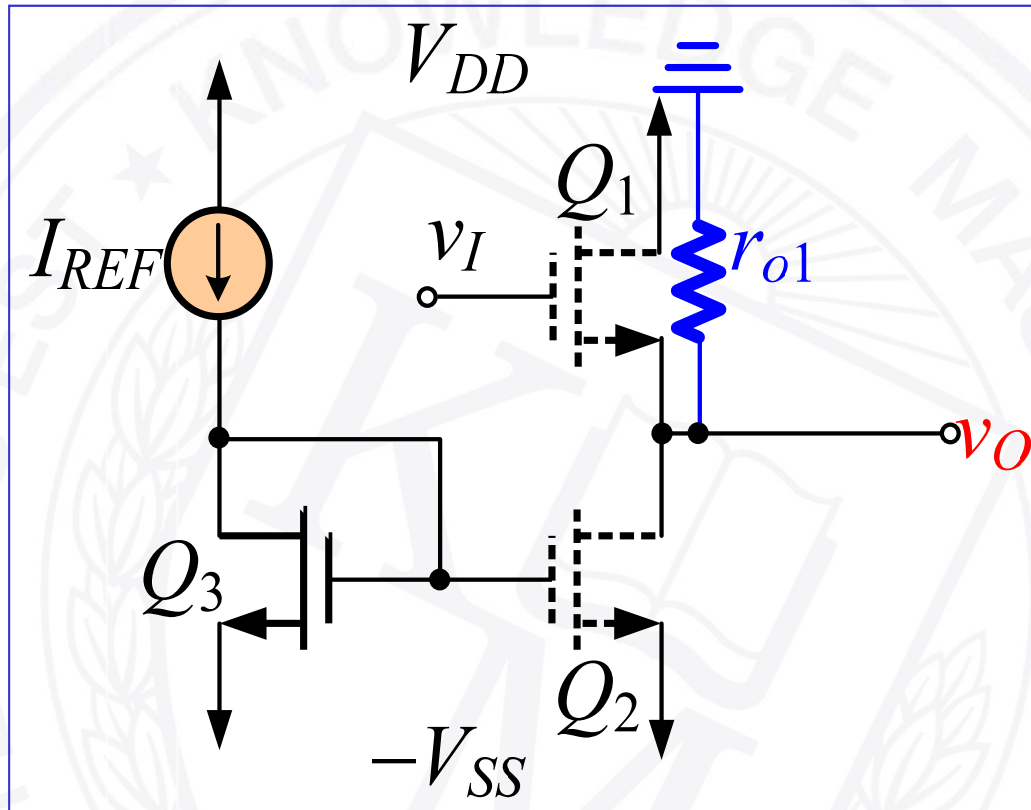


Q1 & Q2: Saturation

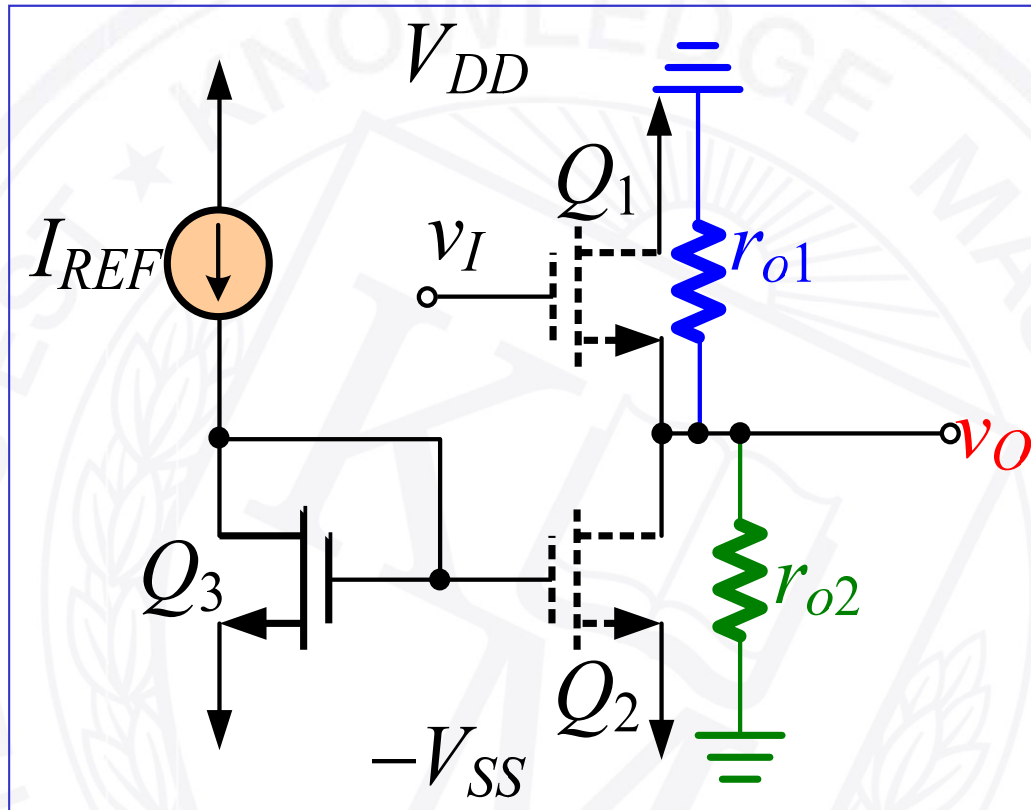
Analysis-by-Inspection



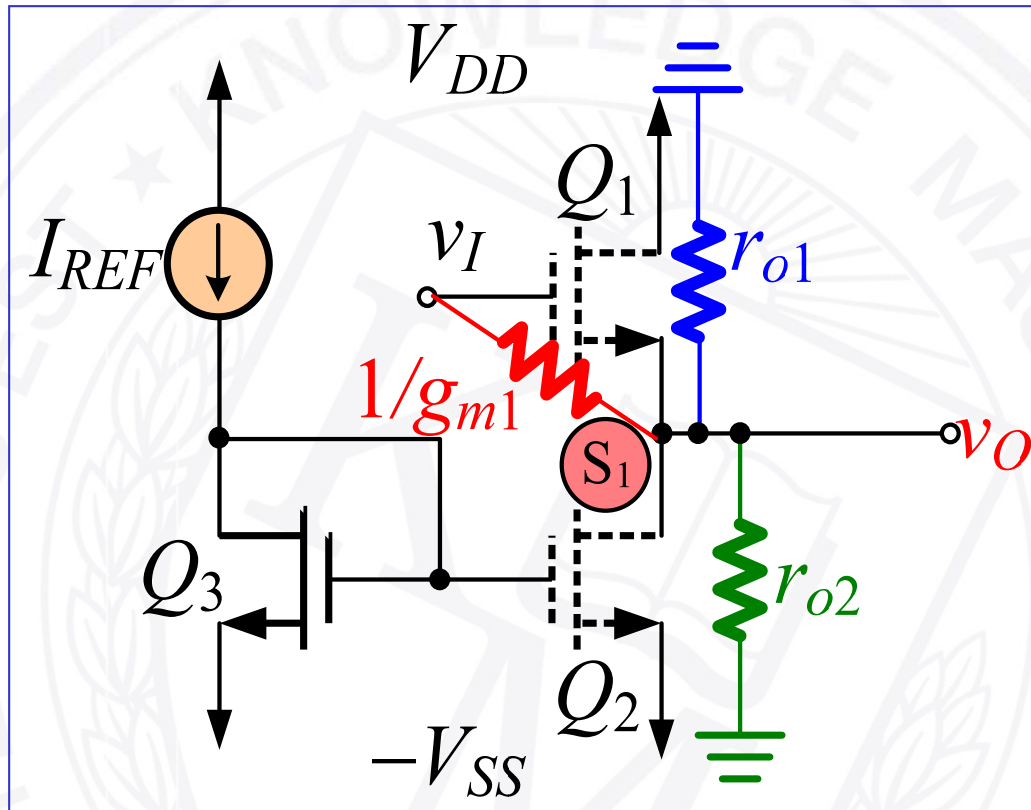
Analysis-by-Inspection



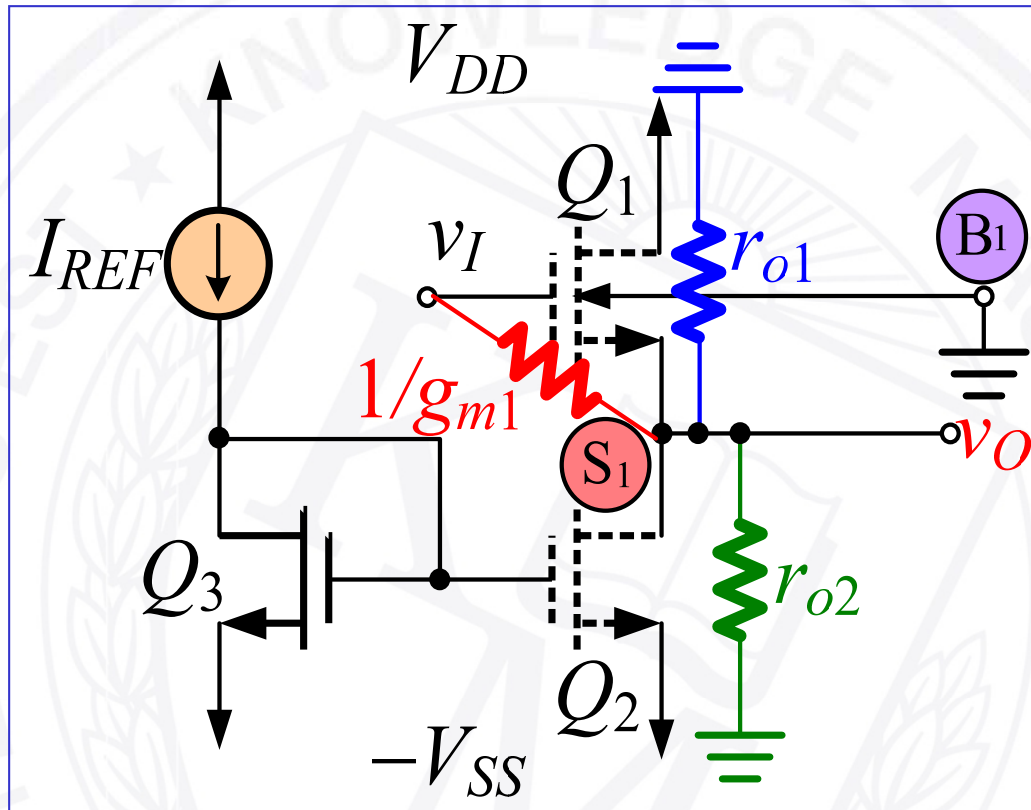
Analysis-by-Inspection



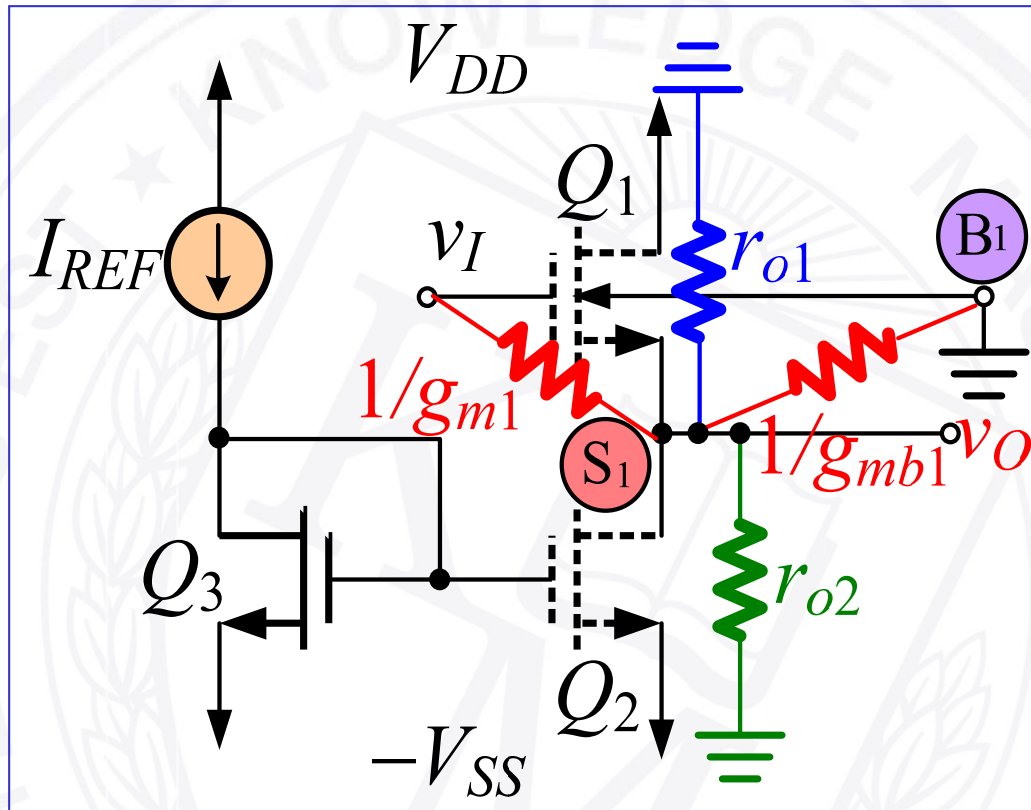
Analysis-by-Inspection, What Else?



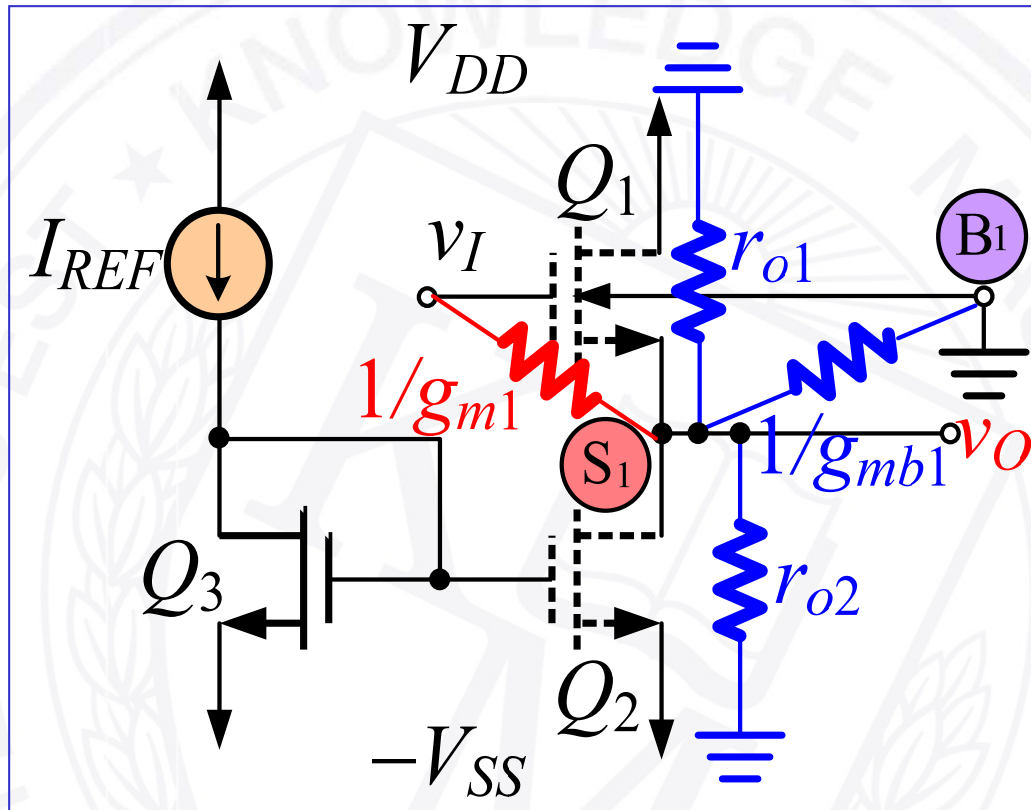
Analysis-by-Inspection



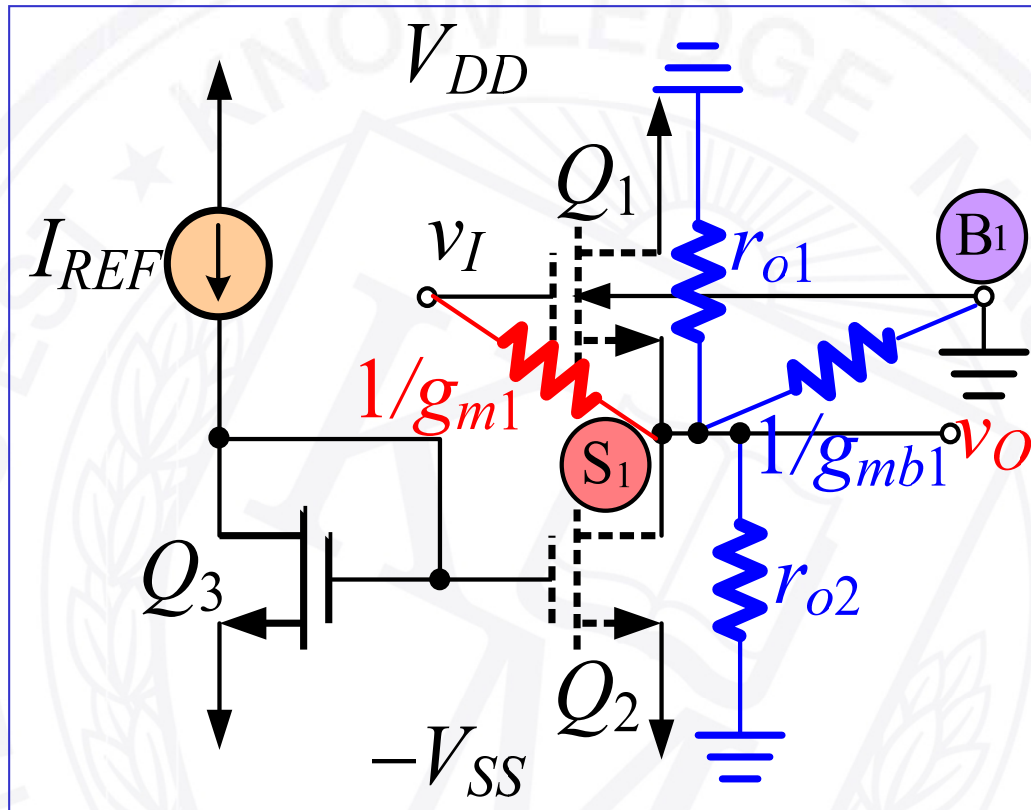
Analysis-by-Inspection



Analysis-by-Inspection

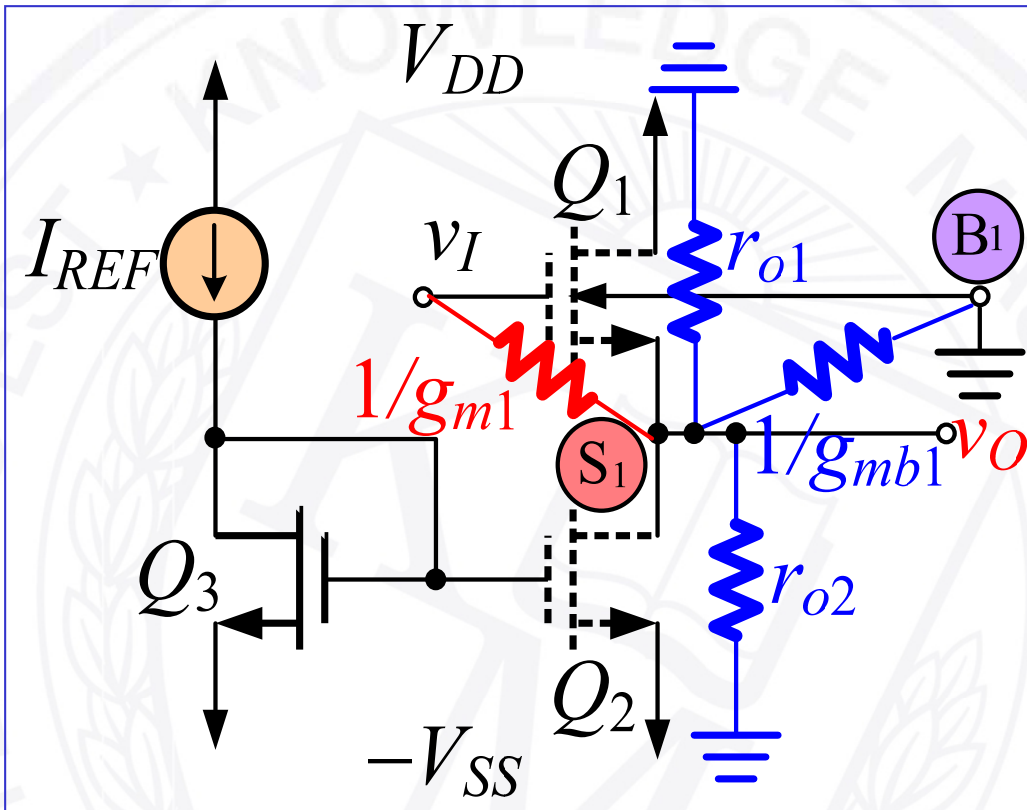


Analysis-by-Inspection



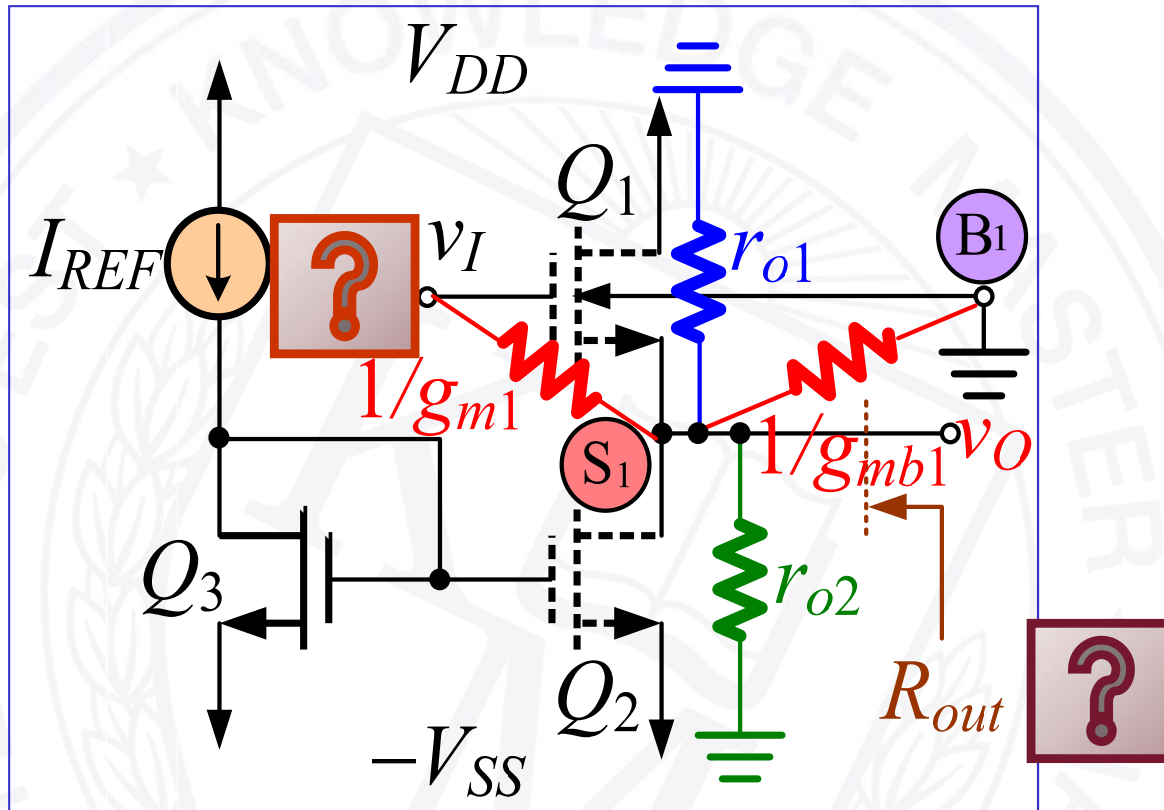
$$A_V \triangleq \frac{v_o}{v_i} =$$

Small-Signal Voltage Gain

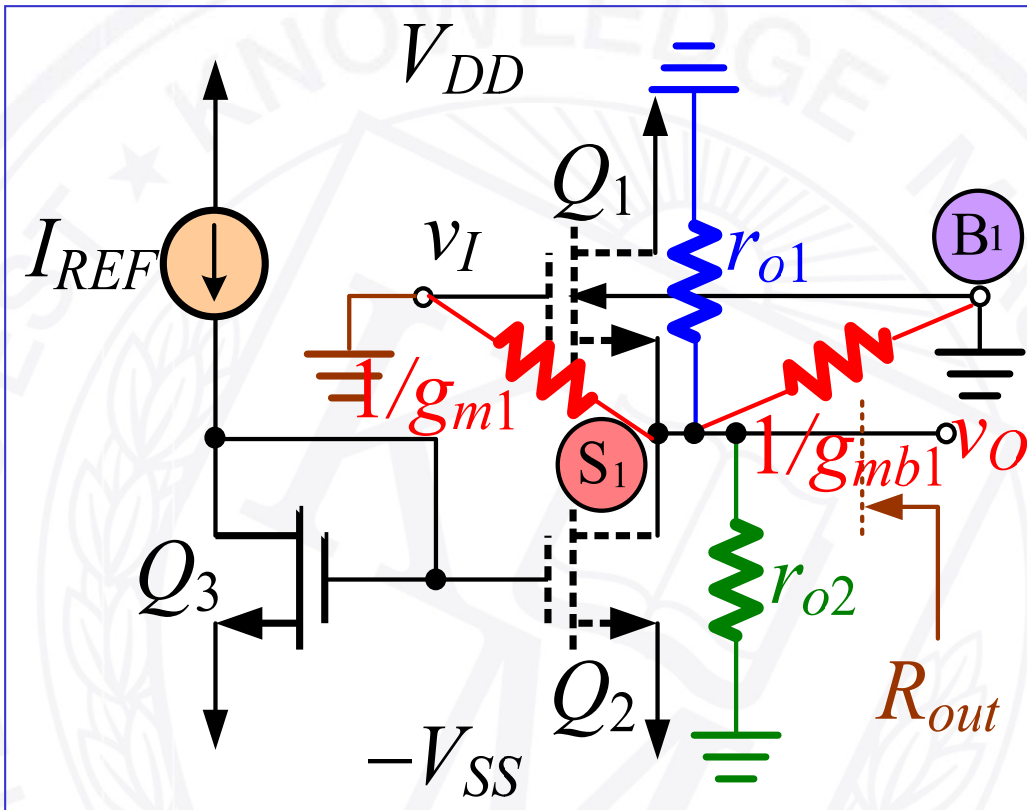


$$A_V \triangleq \frac{v_o}{v_i} = \frac{\left(r_{o1} \parallel r_{o2} \parallel \frac{1}{g_{mb1}} \right)}{\frac{1}{g_{m1}} + \left(r_{o1} \parallel r_{o2} \parallel \frac{1}{g_{mb1}} \right)}$$

Output Resistance



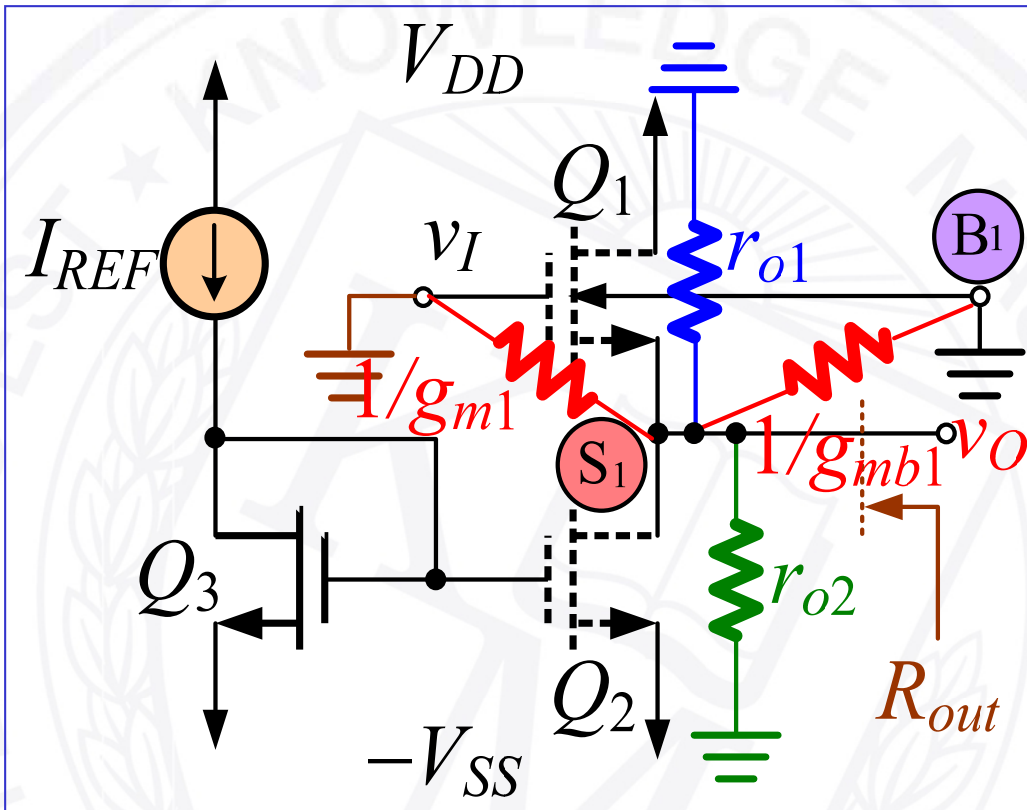
Output Resistance



$$R_{out} =$$

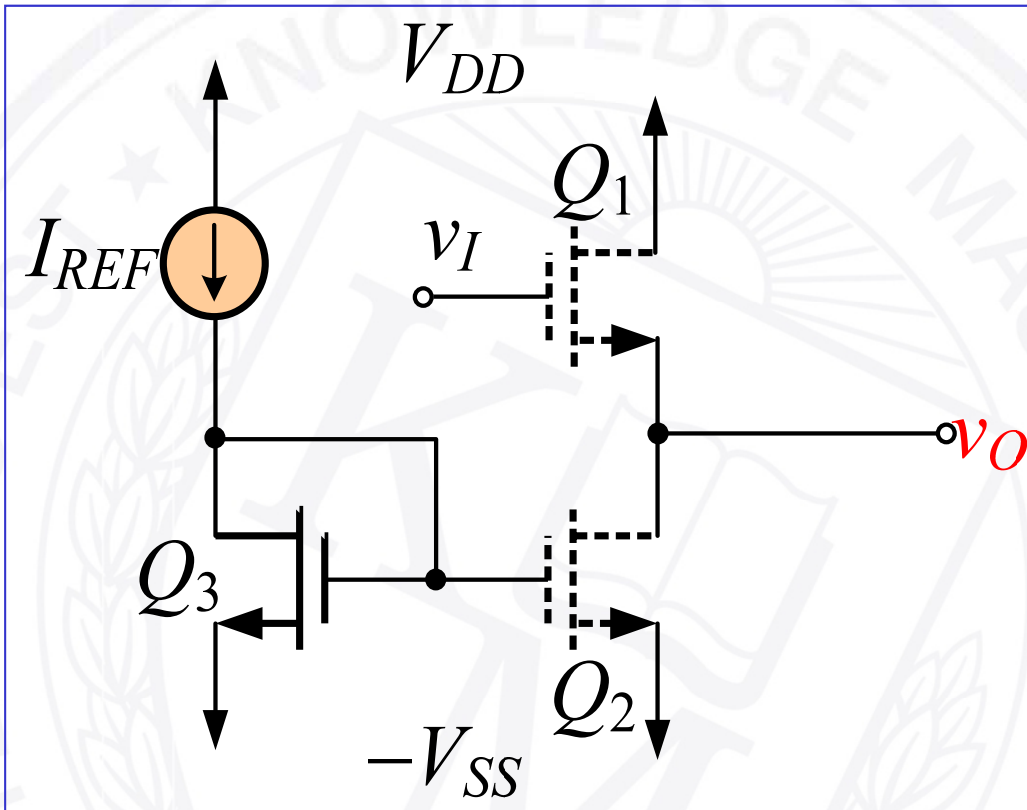


Output Resistance



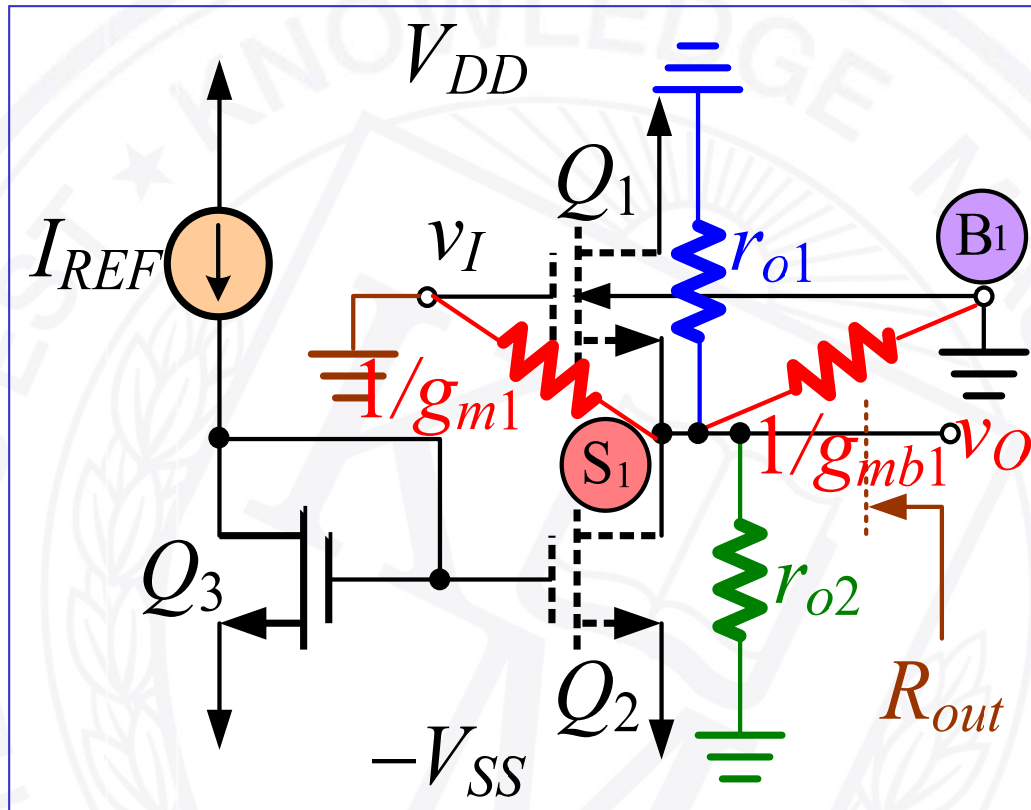
$$R_{out} = r_{o1} \parallel r_{o2} \parallel \frac{1}{g_{m1}} \parallel \frac{1}{g_{mb1}}$$

Summary



$$R_{out} = r_{o1} \parallel r_{o2} \parallel \frac{1}{g_{m1}} \parallel \frac{1}{g_{mb1}}$$

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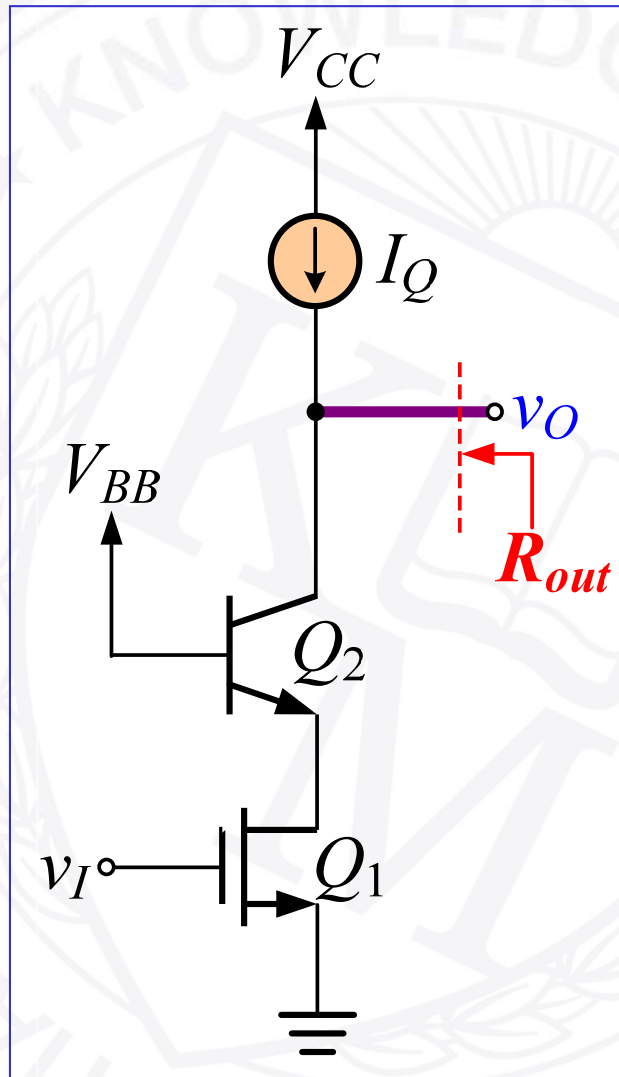
BiCMOS cascode

- Finesse
- Analysis-by-inspection

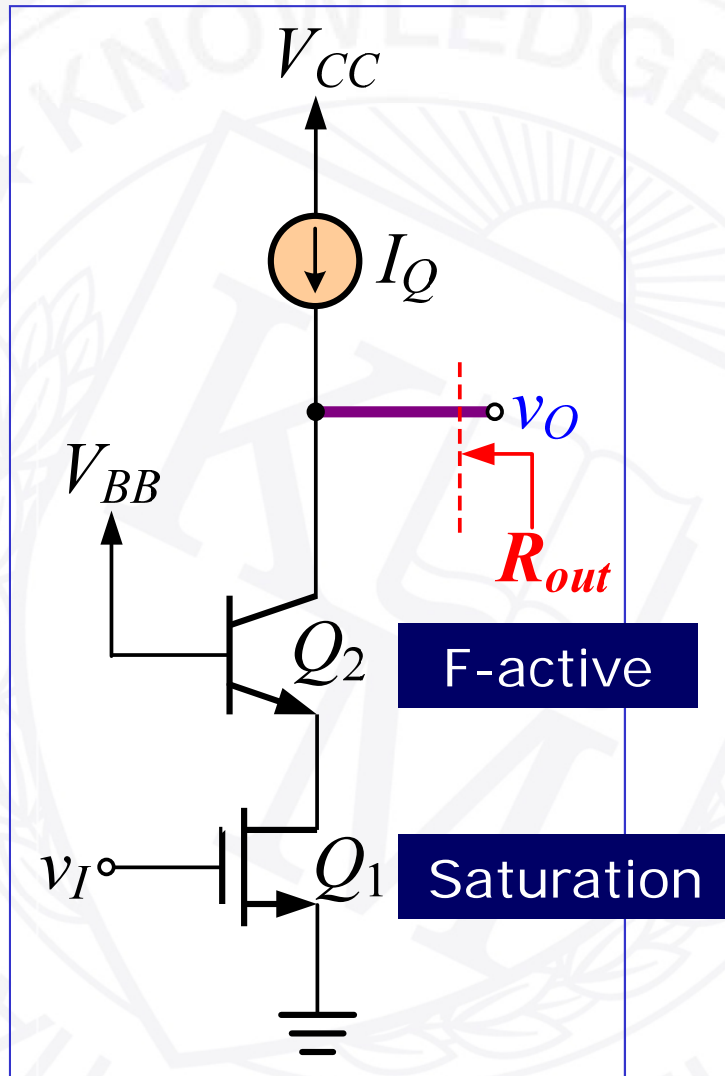
BiCMOS double cascode

- Finesse
- Analysis-by-inspection

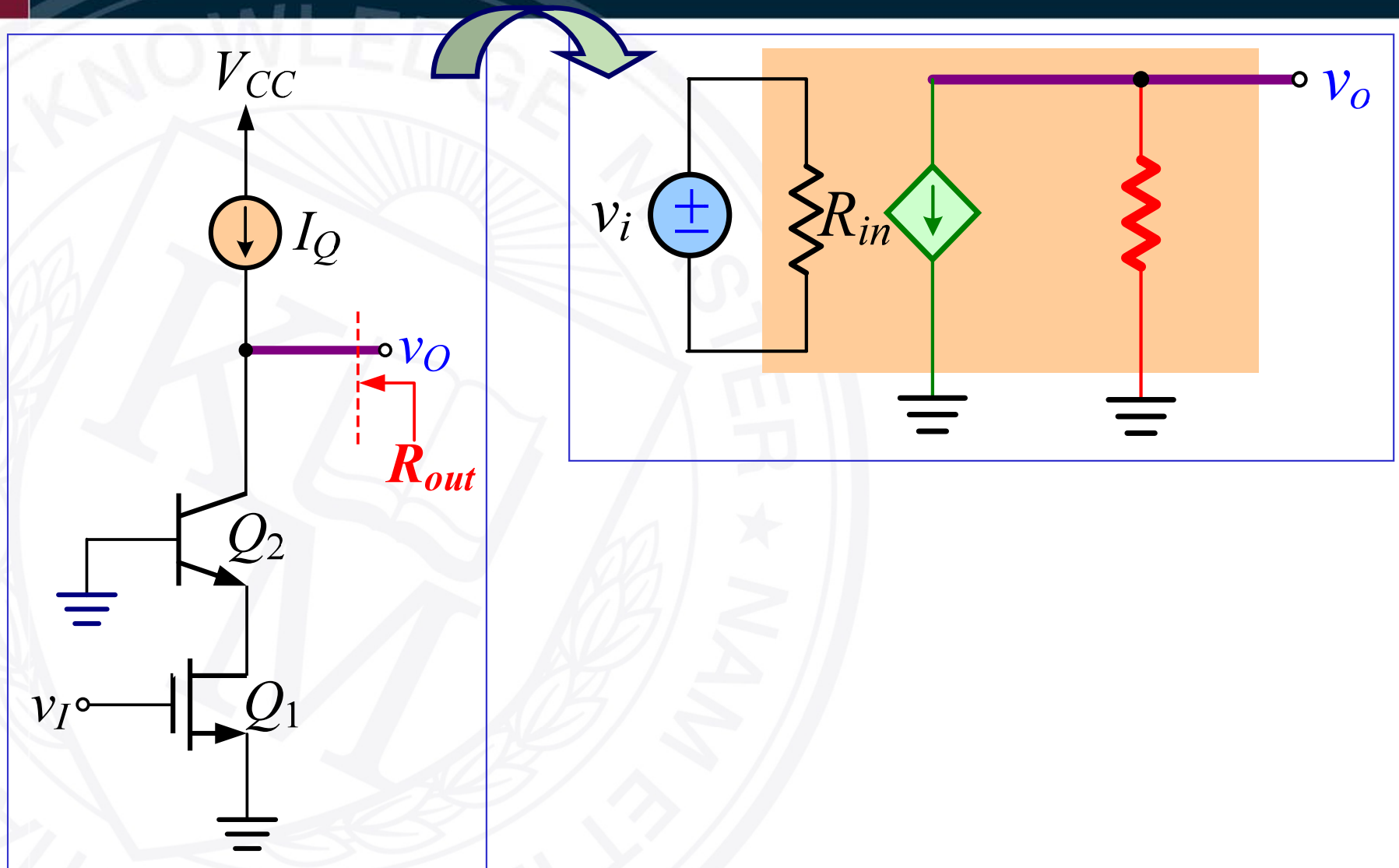
BiCMOS Cascode Amplifier



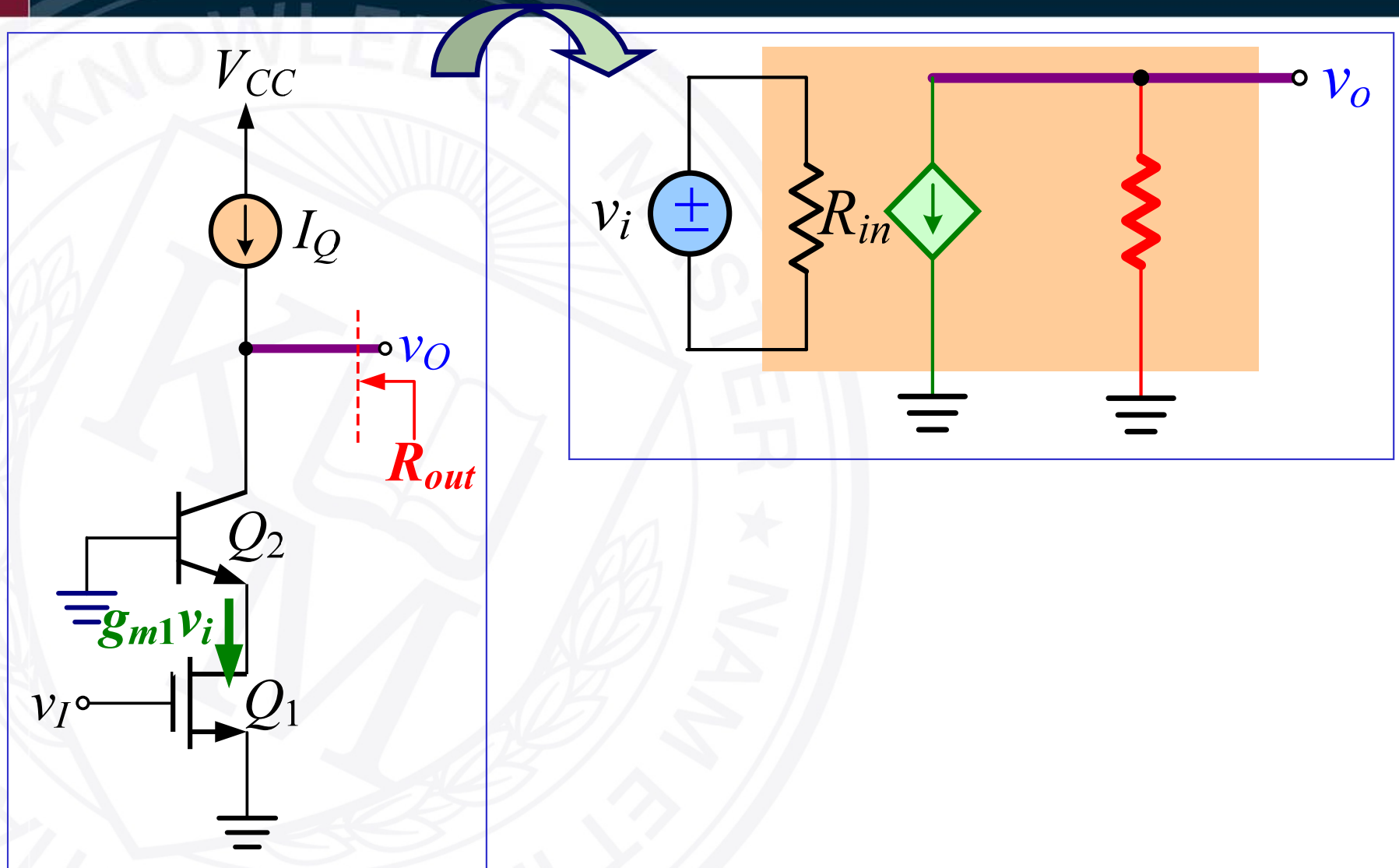
Assumption: Operating Point



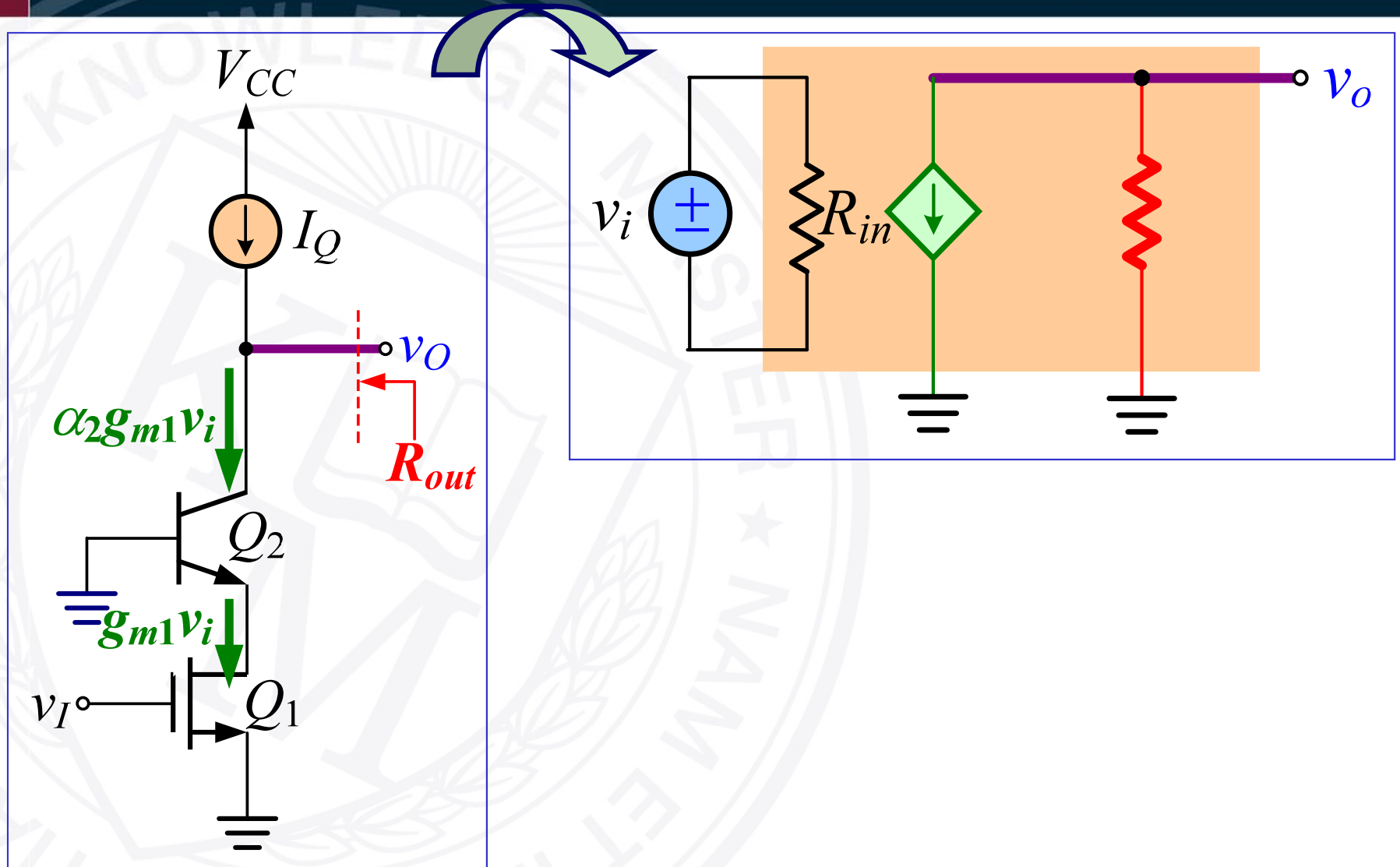
Finesse: Norton Equivalent



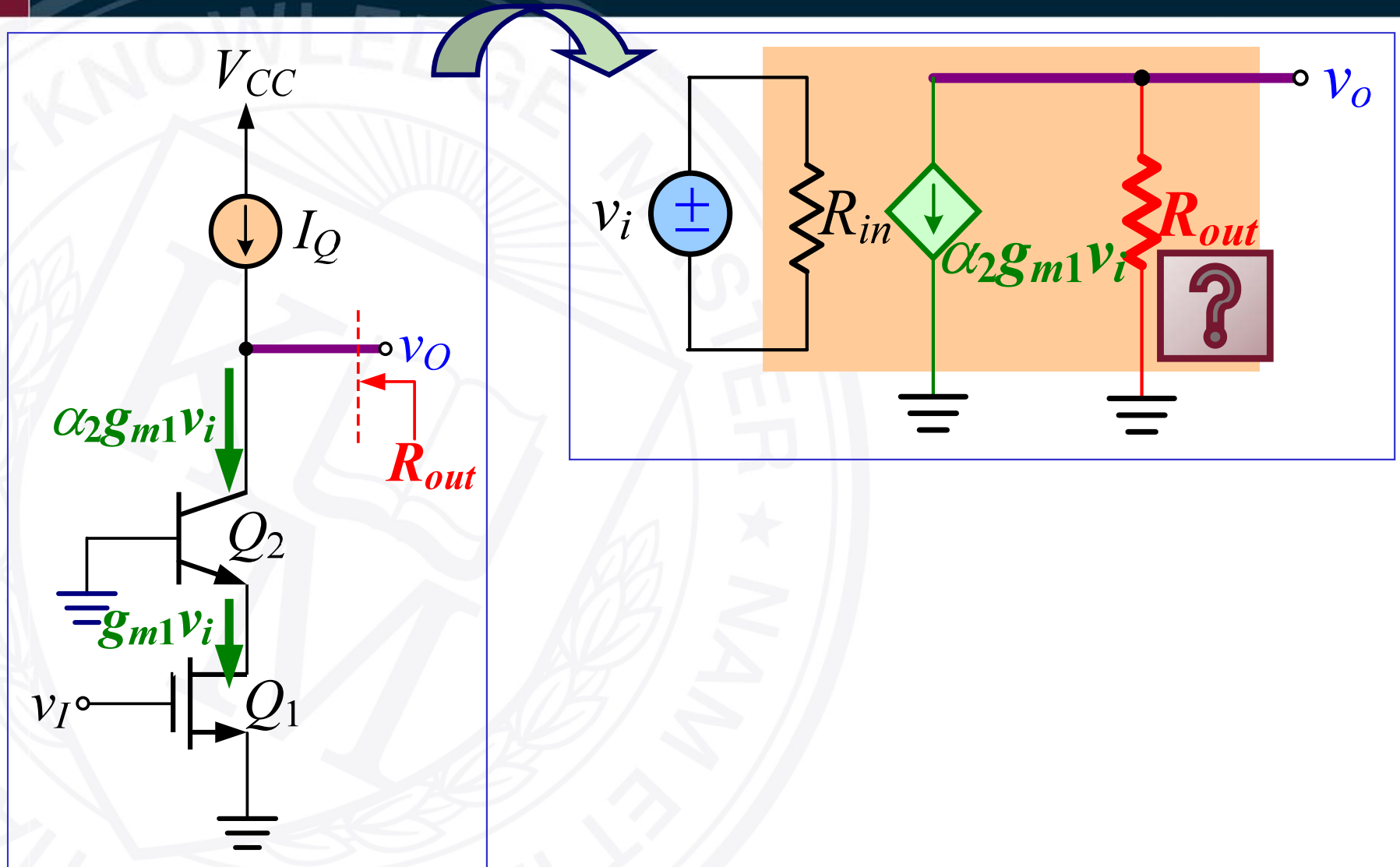
Transconductance



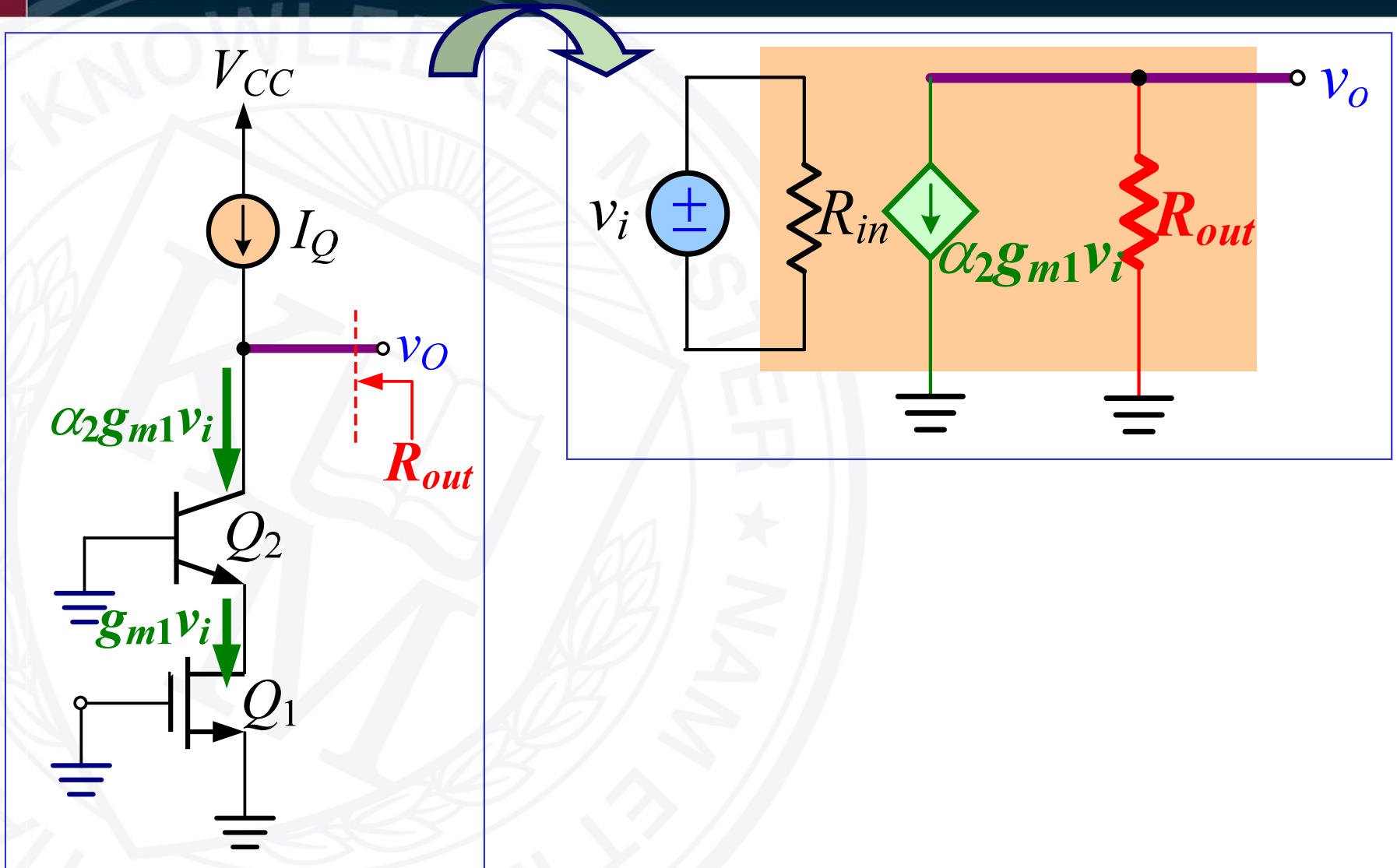
Transconductance



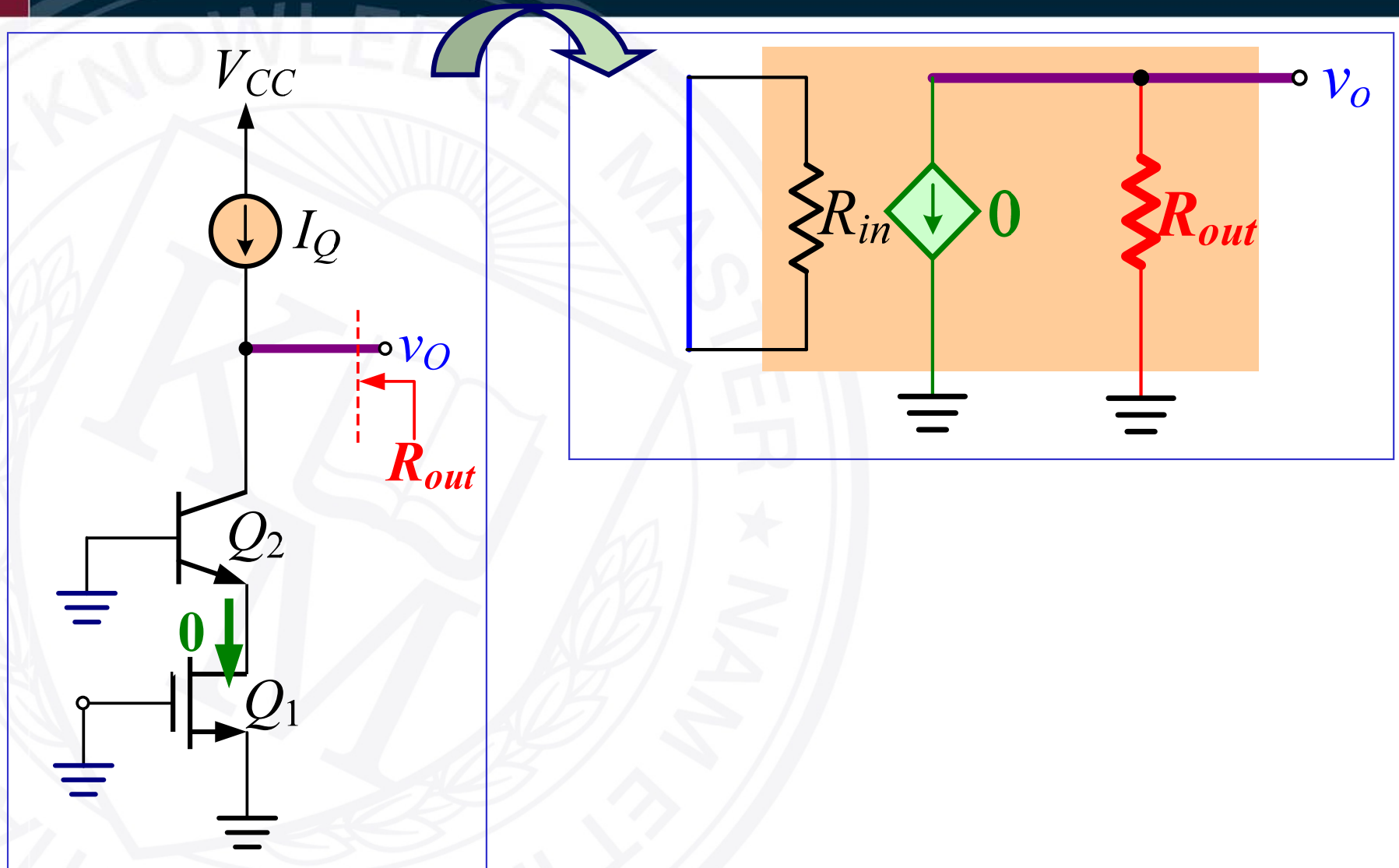
Transconductance



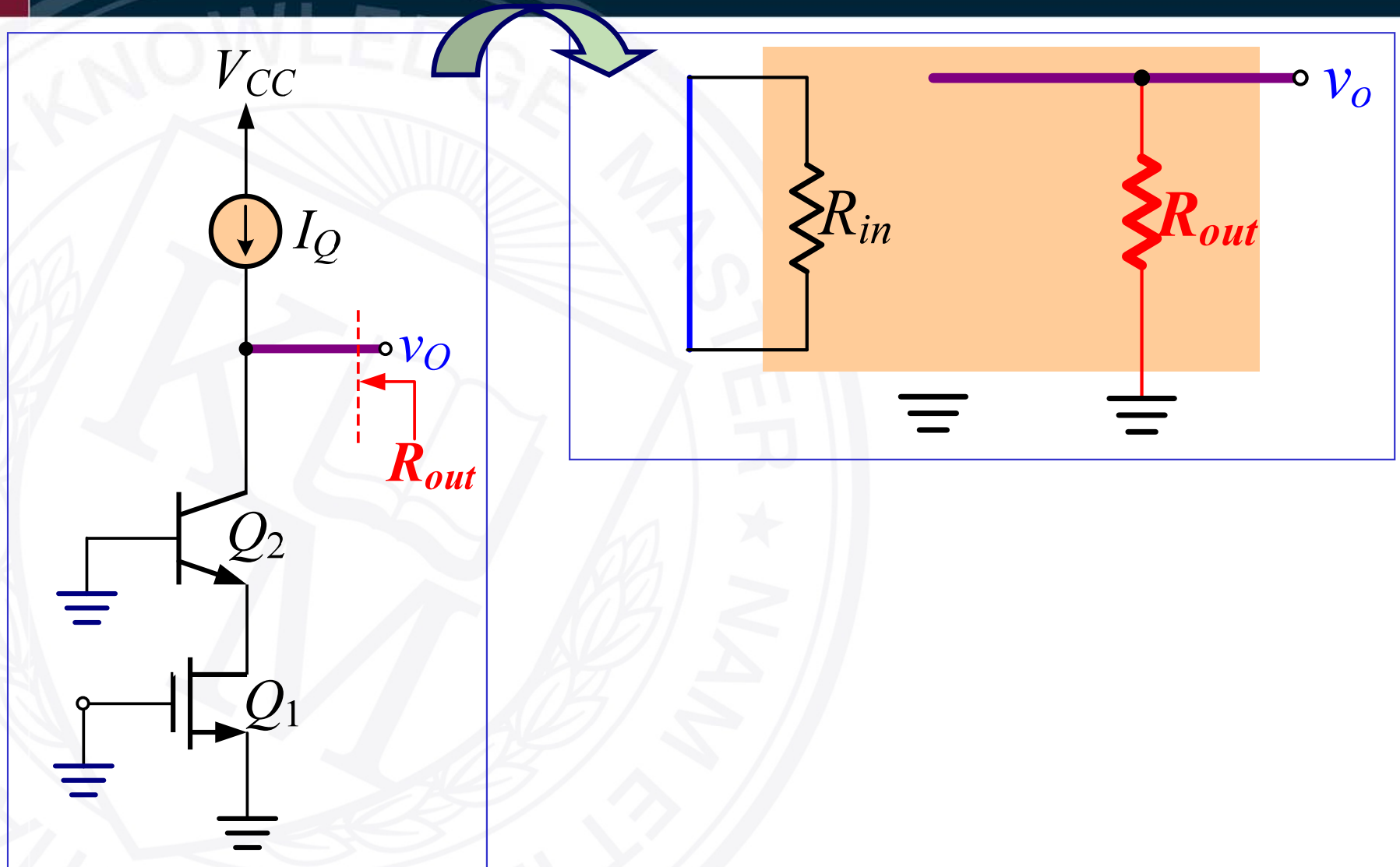
Output Resistance



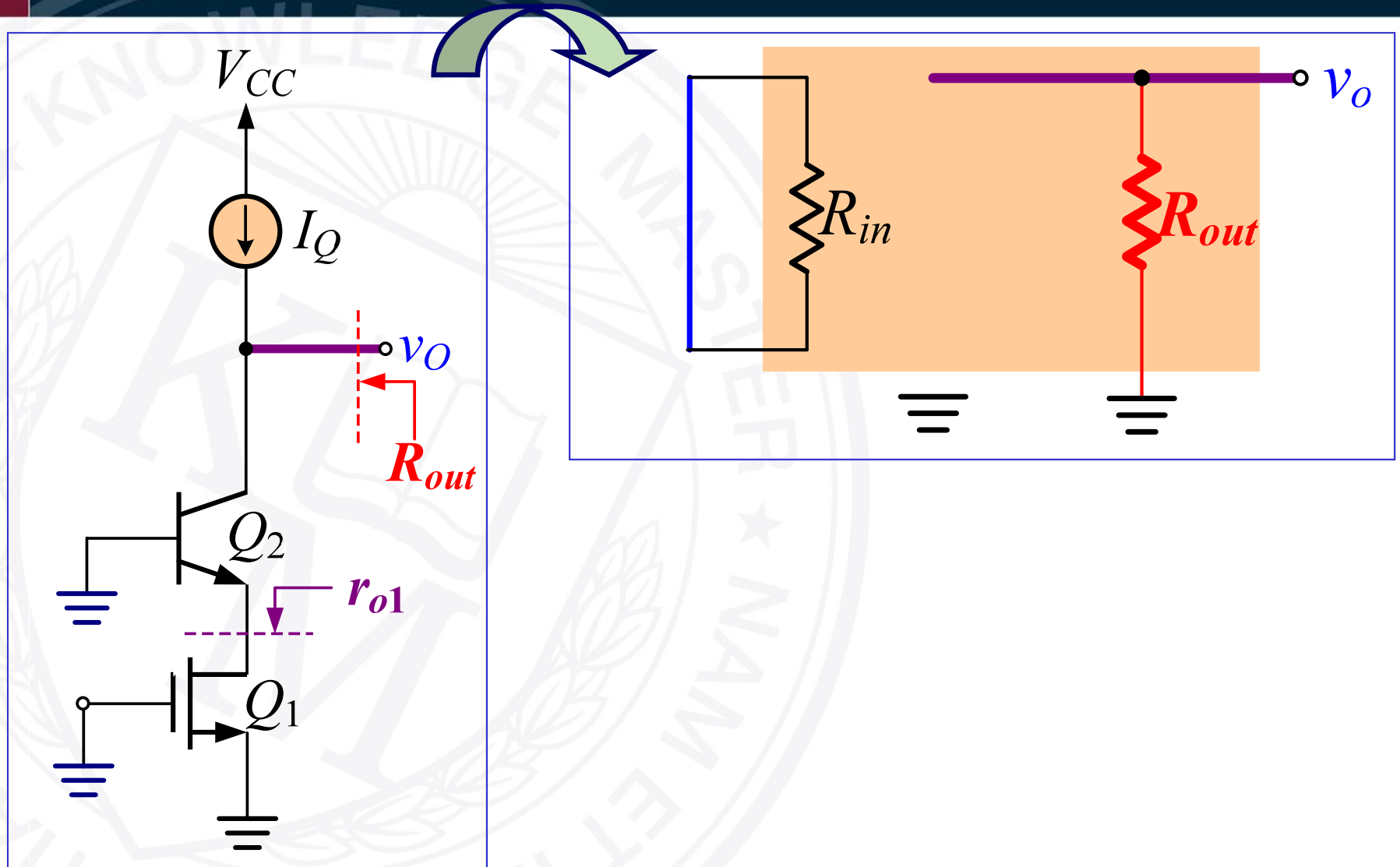
Output Resistance



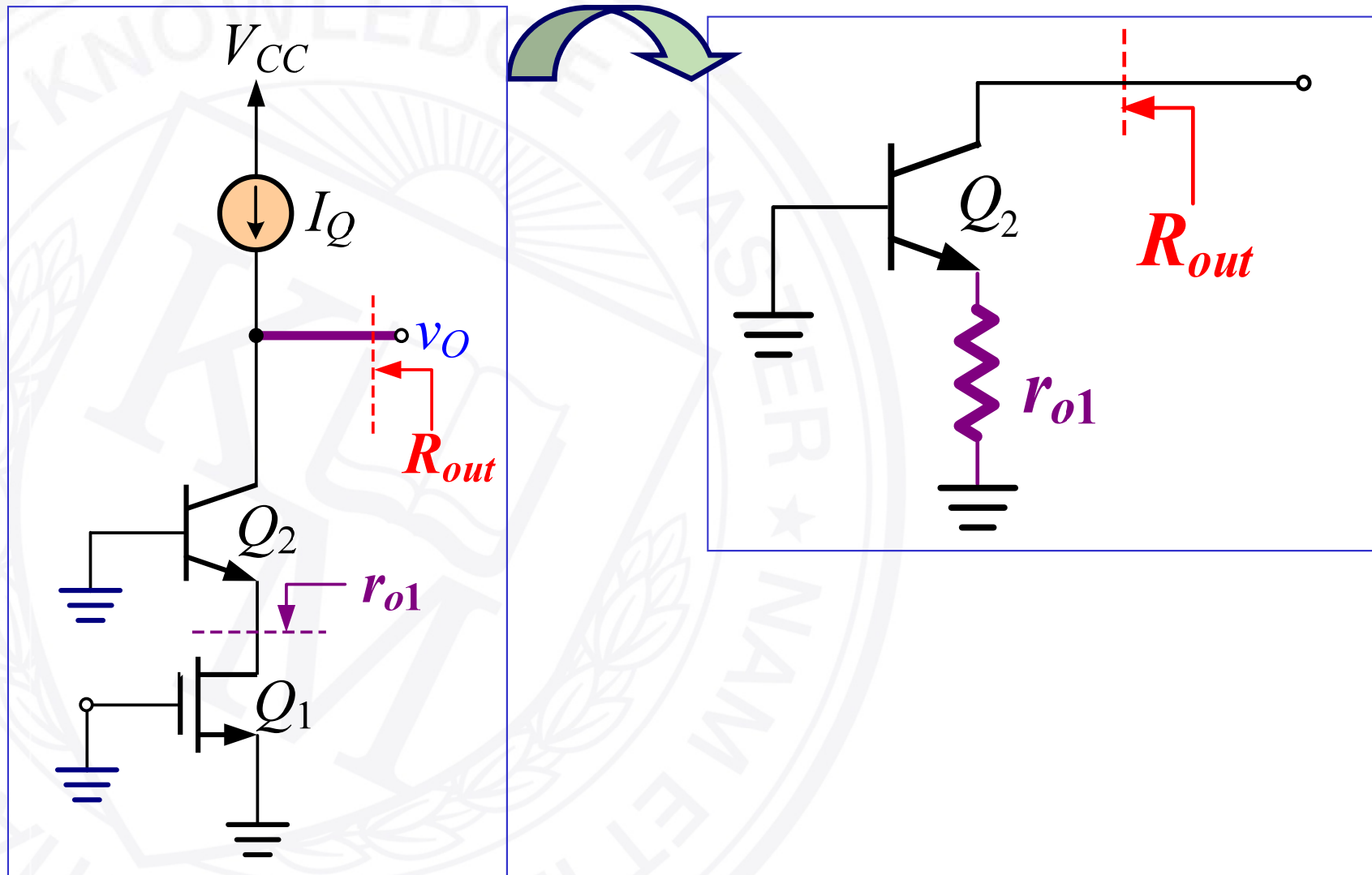
Output Resistance



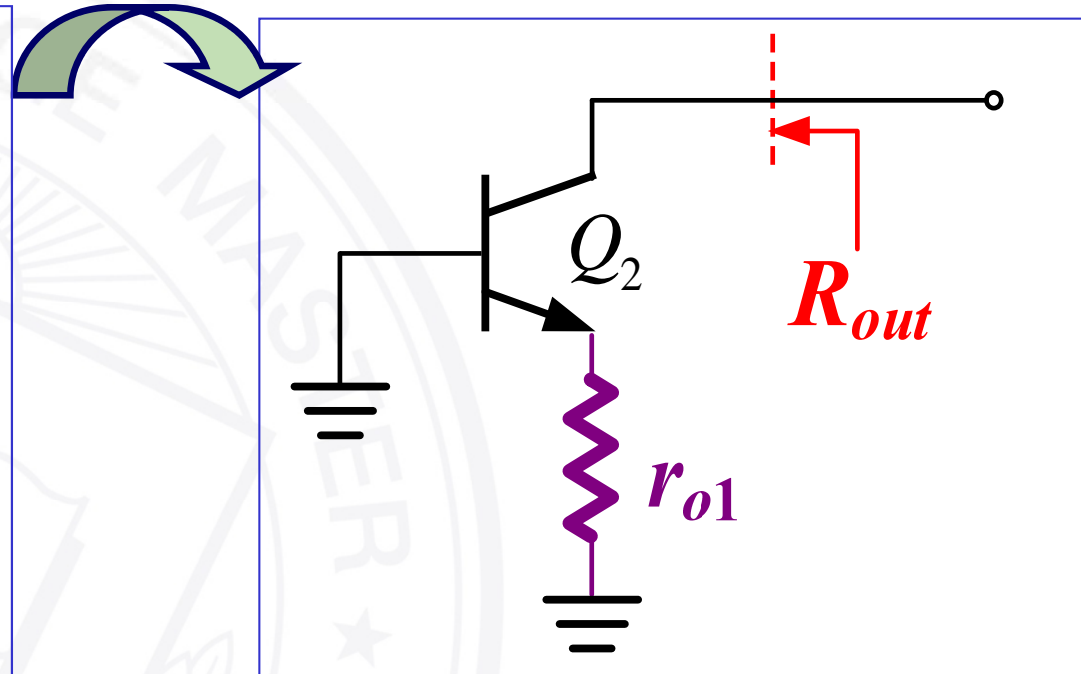
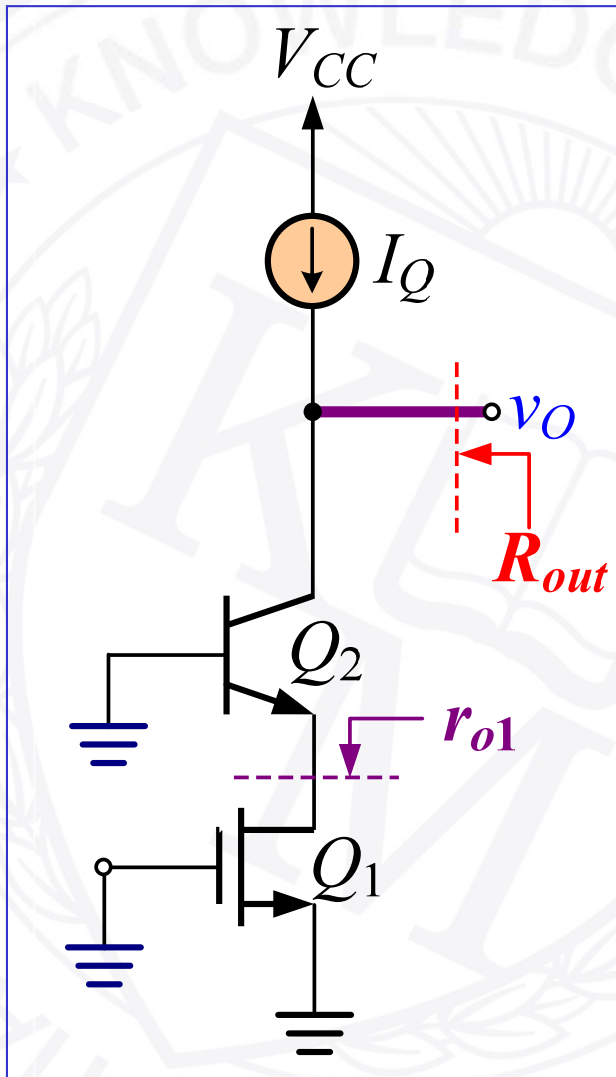
Output Resistance



Output Resistance

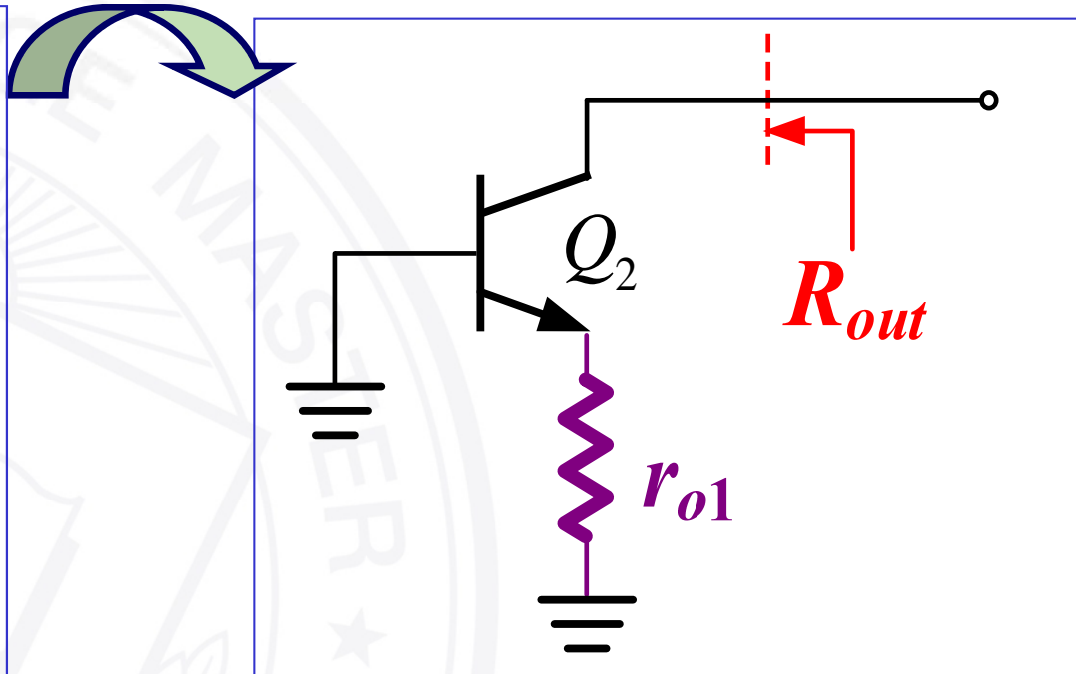
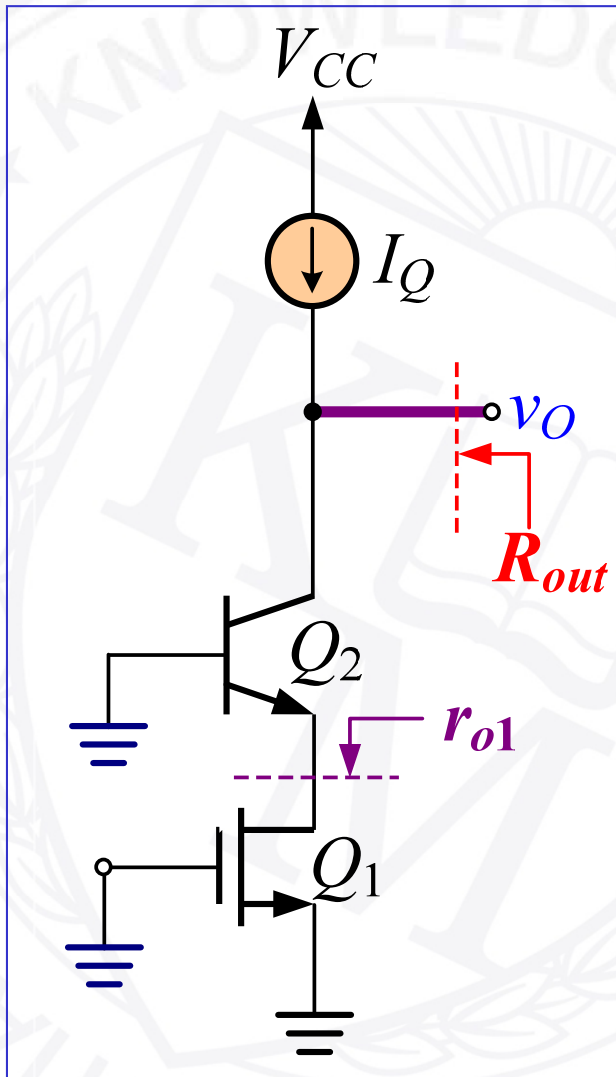


Output Resistance



$$R_{out} = r_{o2} + (1 + g_{m2}r_{o2})(r_{\pi 2} \parallel r_{o1})$$

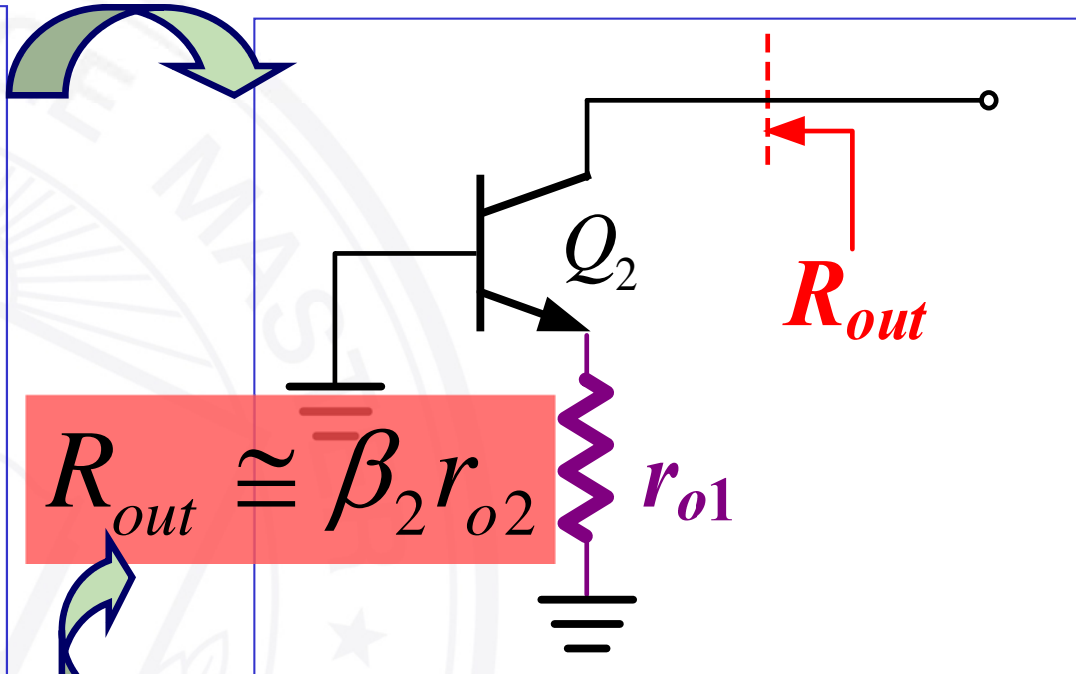
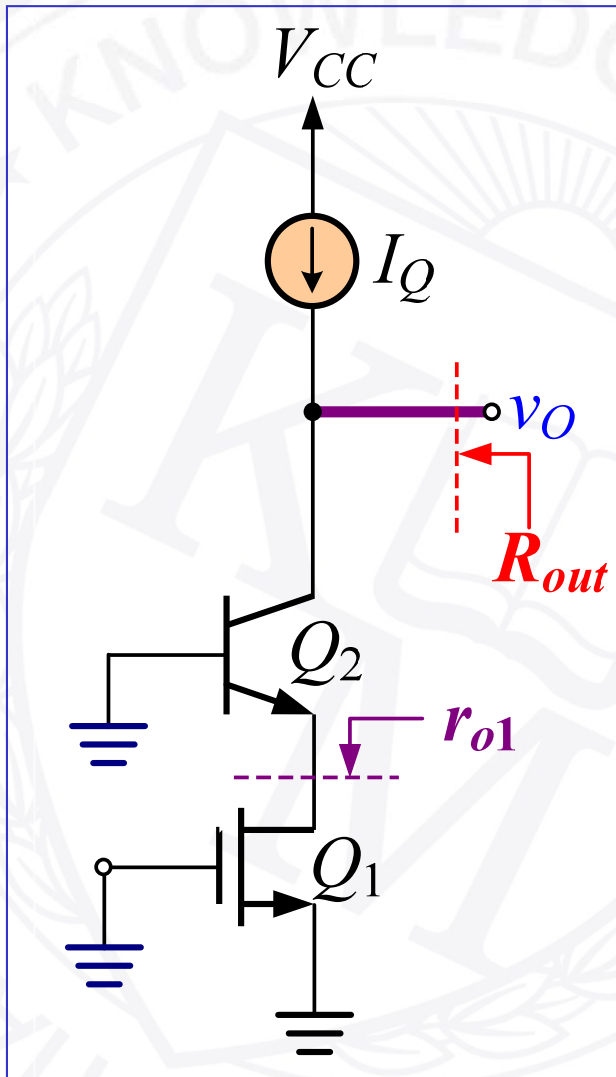
Output Resistance



$$R_{out} = r_{o2} + (1 + g_{m2} r_{o2})(r_{\pi2} \parallel r_{o1})$$

$$= r_{o2} + g_{m2} r_{o2} r_{\pi2} \cong (1 + \beta_2) r_{o2}$$

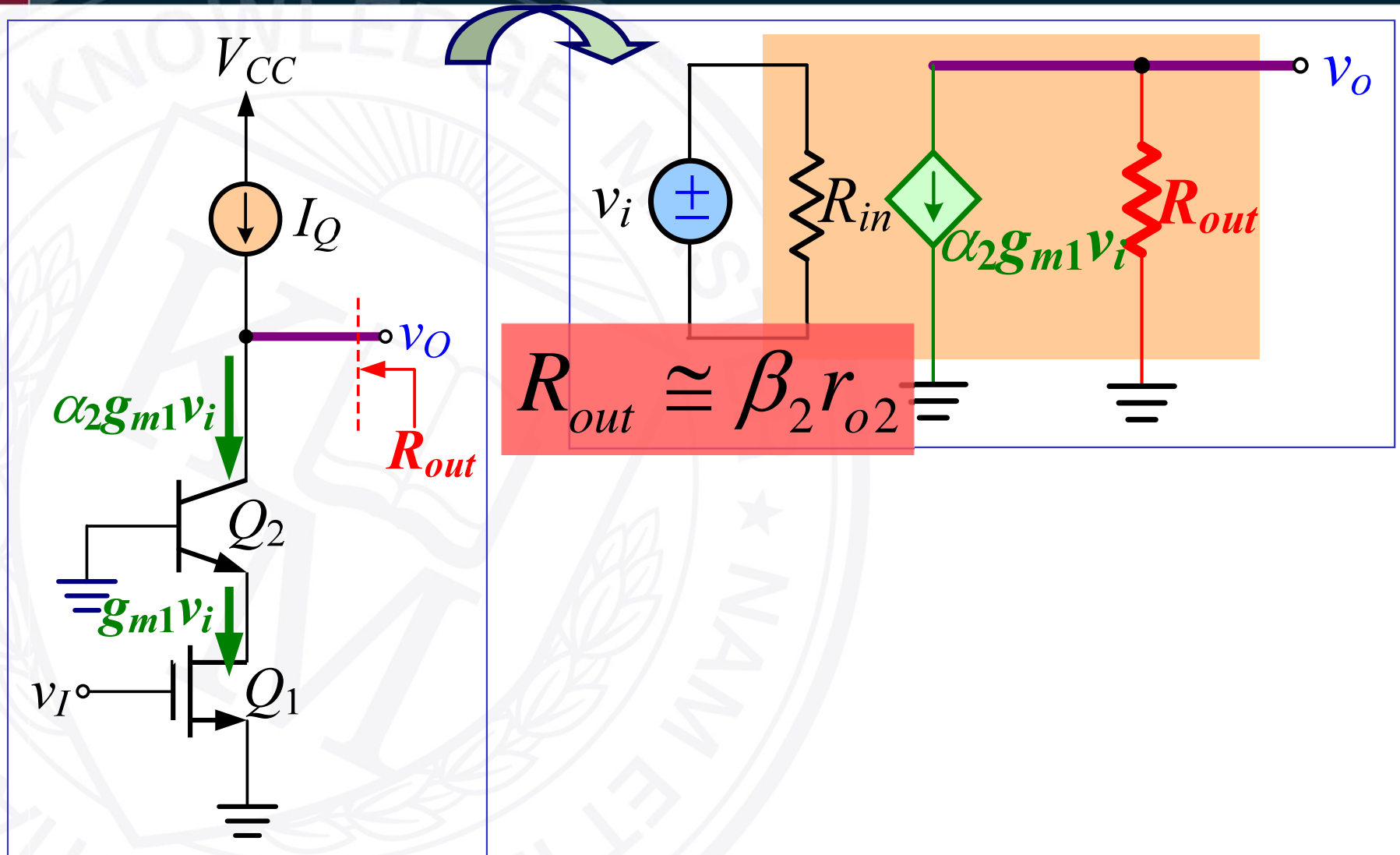
Output Resistance



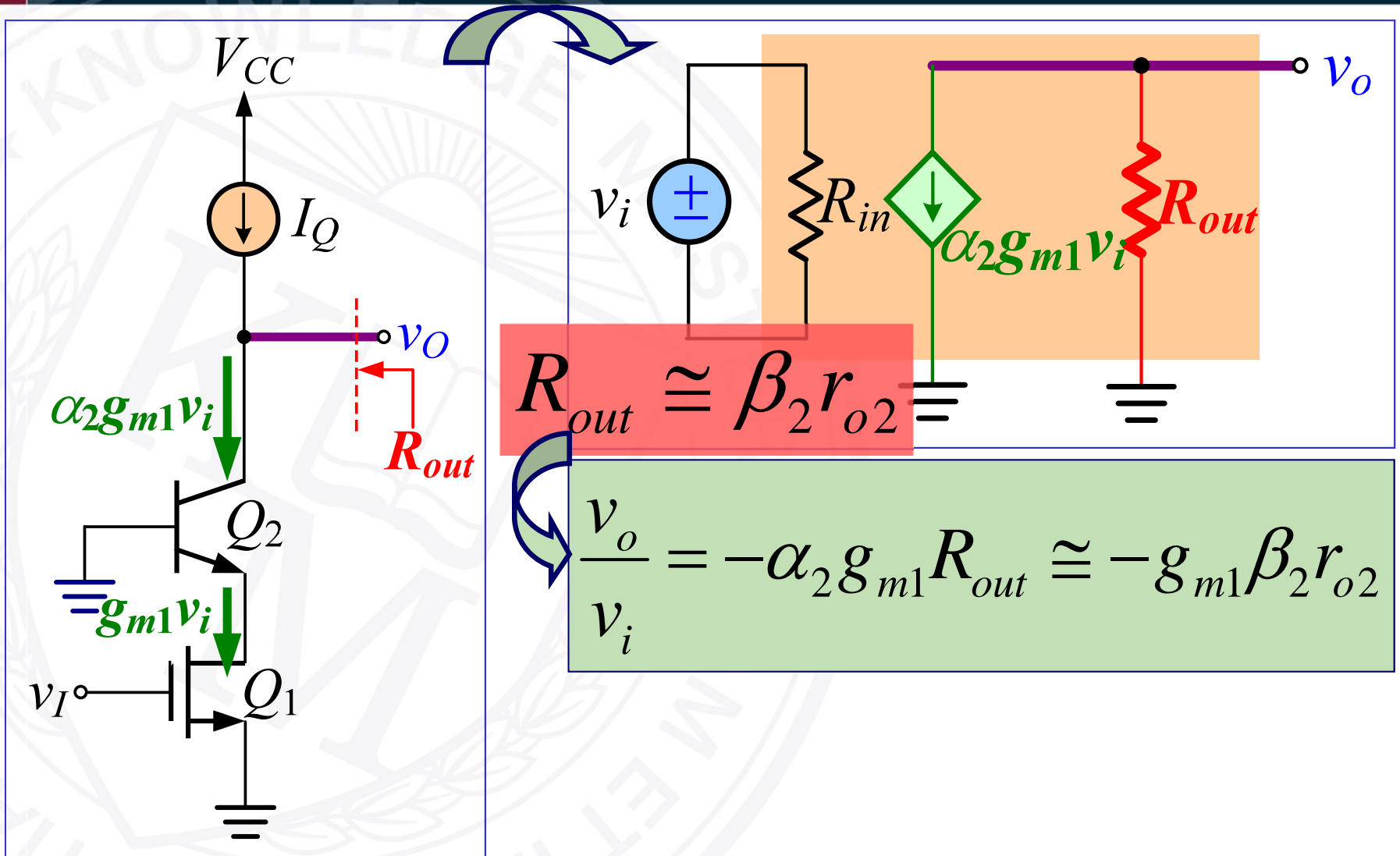
$$R_{out} = r_{o2} + (1 + g_{m2} r_{o2})(r_{\pi 2} \parallel r_{o1})$$

$$= r_{o2} + g_{m2} r_{o2} r_{\pi 2} \cong (1 + \beta_2) r_{o2}$$

Norton Equivalent Circuit



Small-Signal Voltage Gain



Outline

CMOS amplifiers

- CMOS CS amp
- CMOS source follower

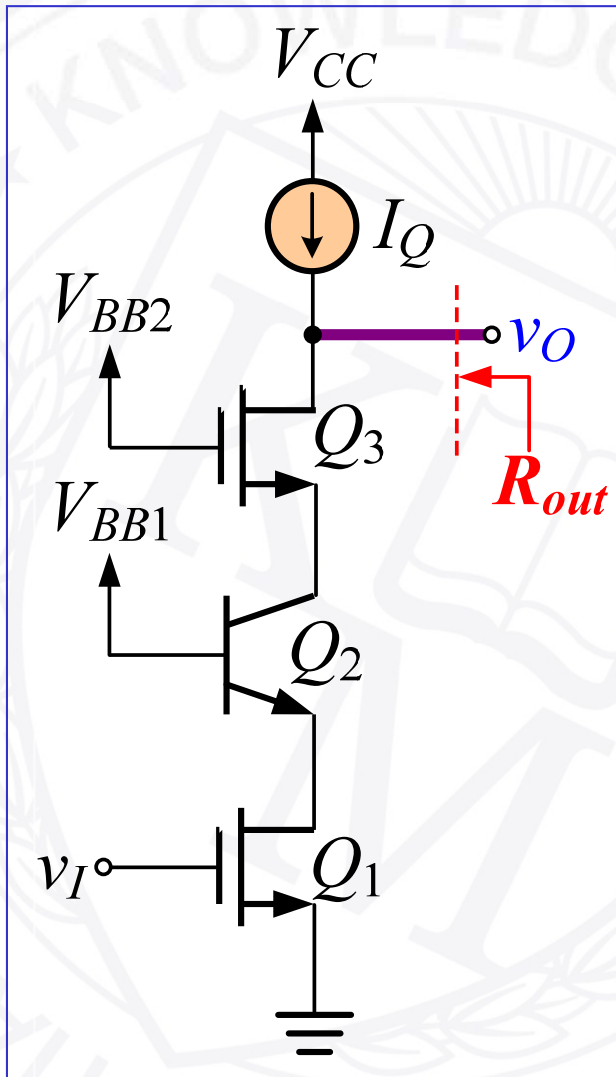
BiCMOS cascode

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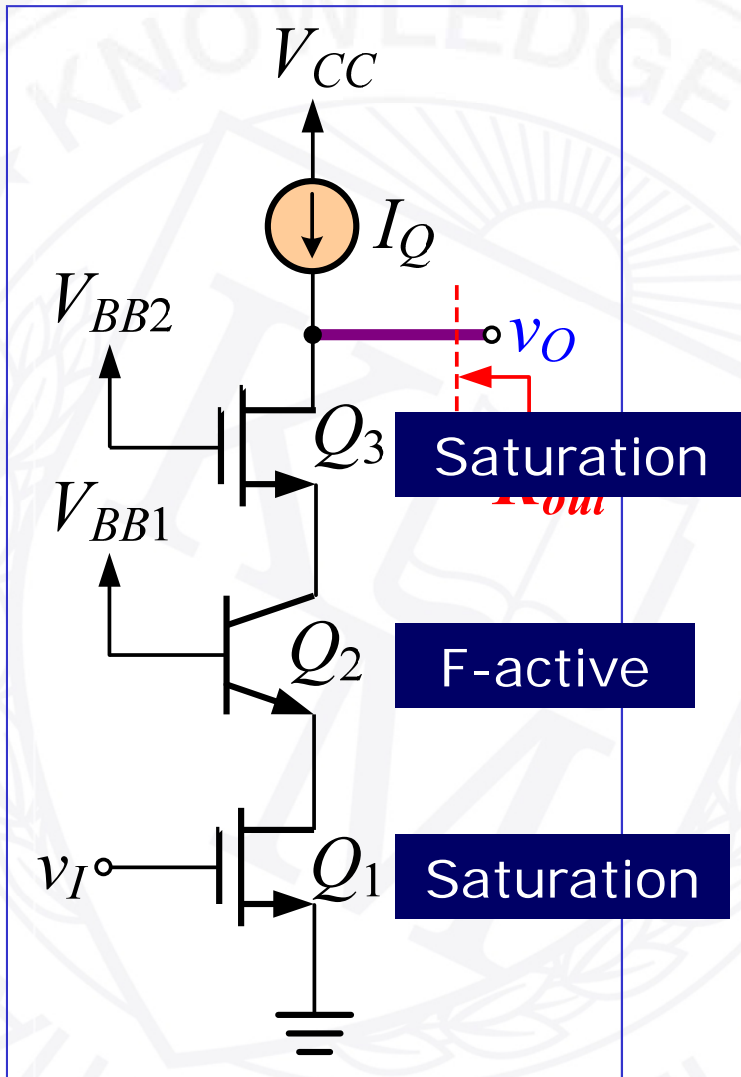
BiCMOS double cascode

- Finesse
- Analysis-by-inspection

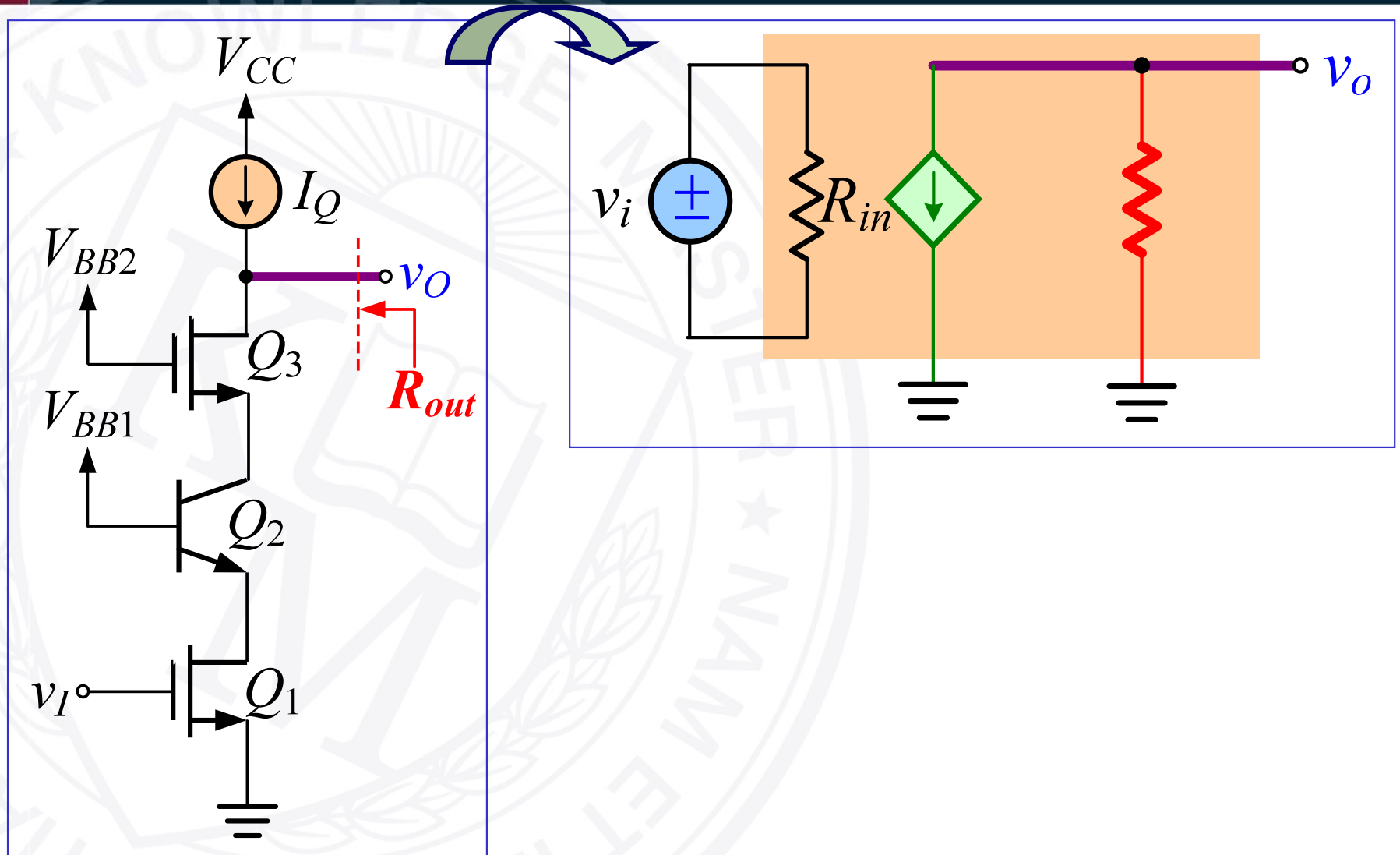
BiCMOS Double Cascode



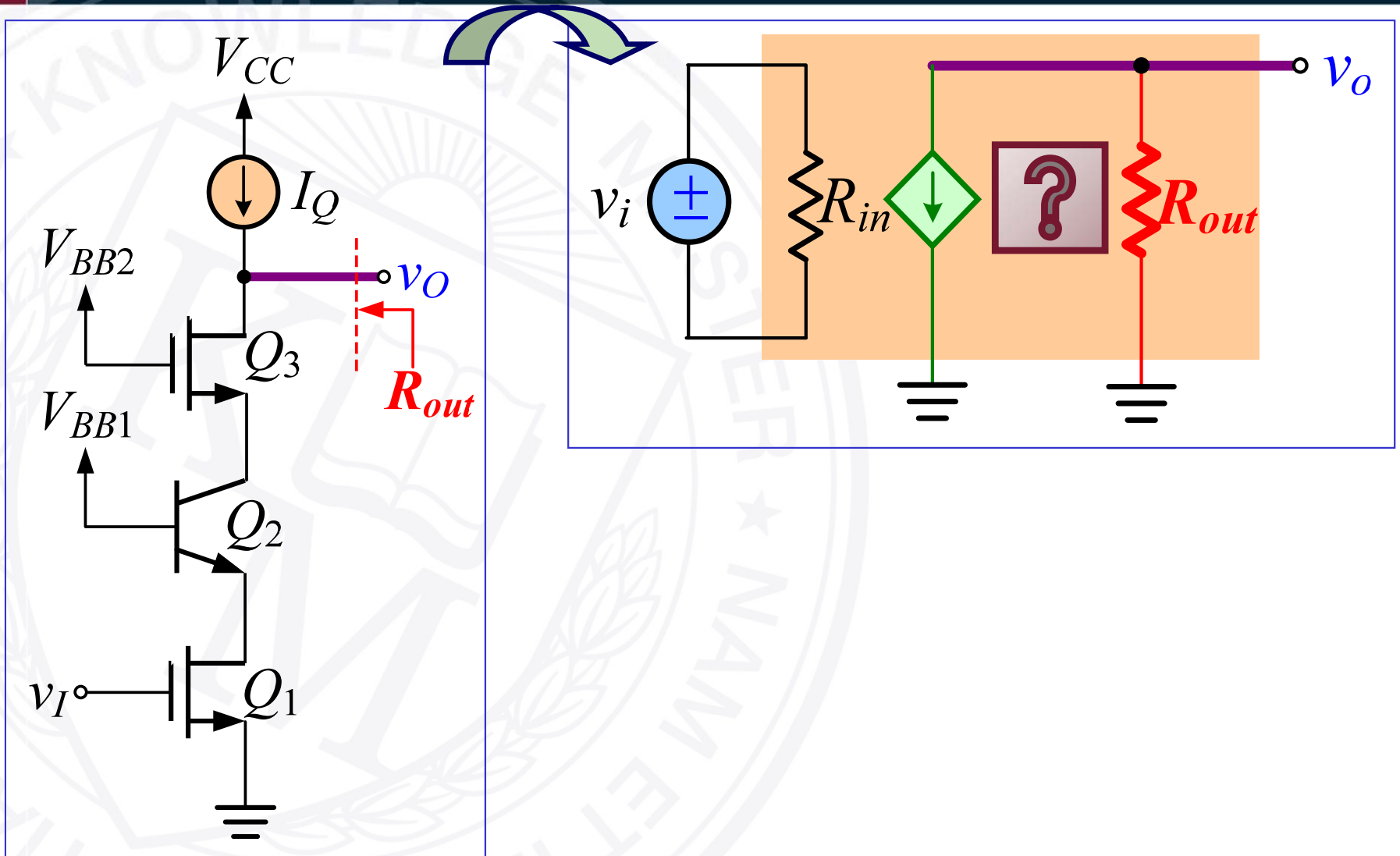
Assumption: Operating Point



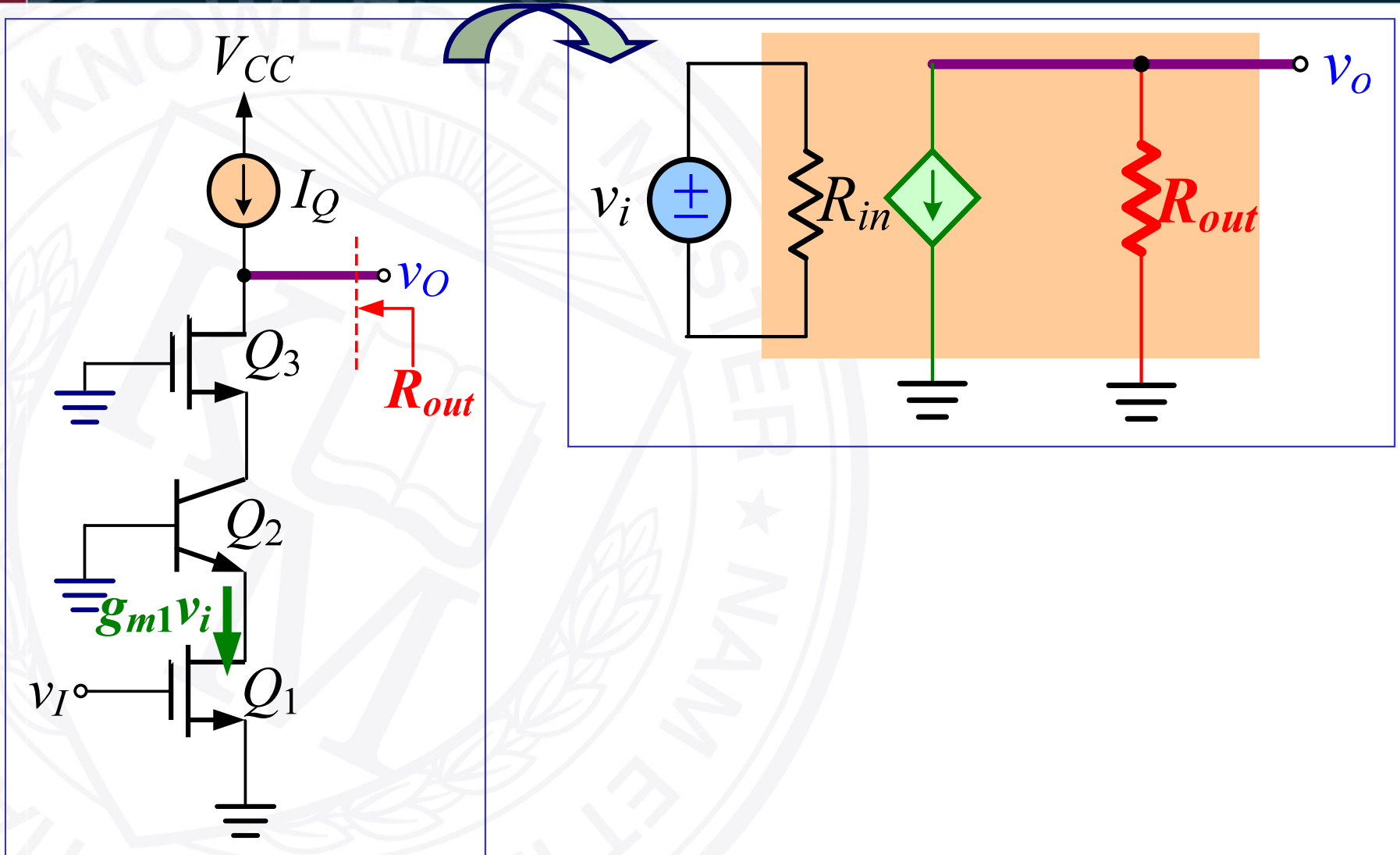
Finesse: Norton Equivalent



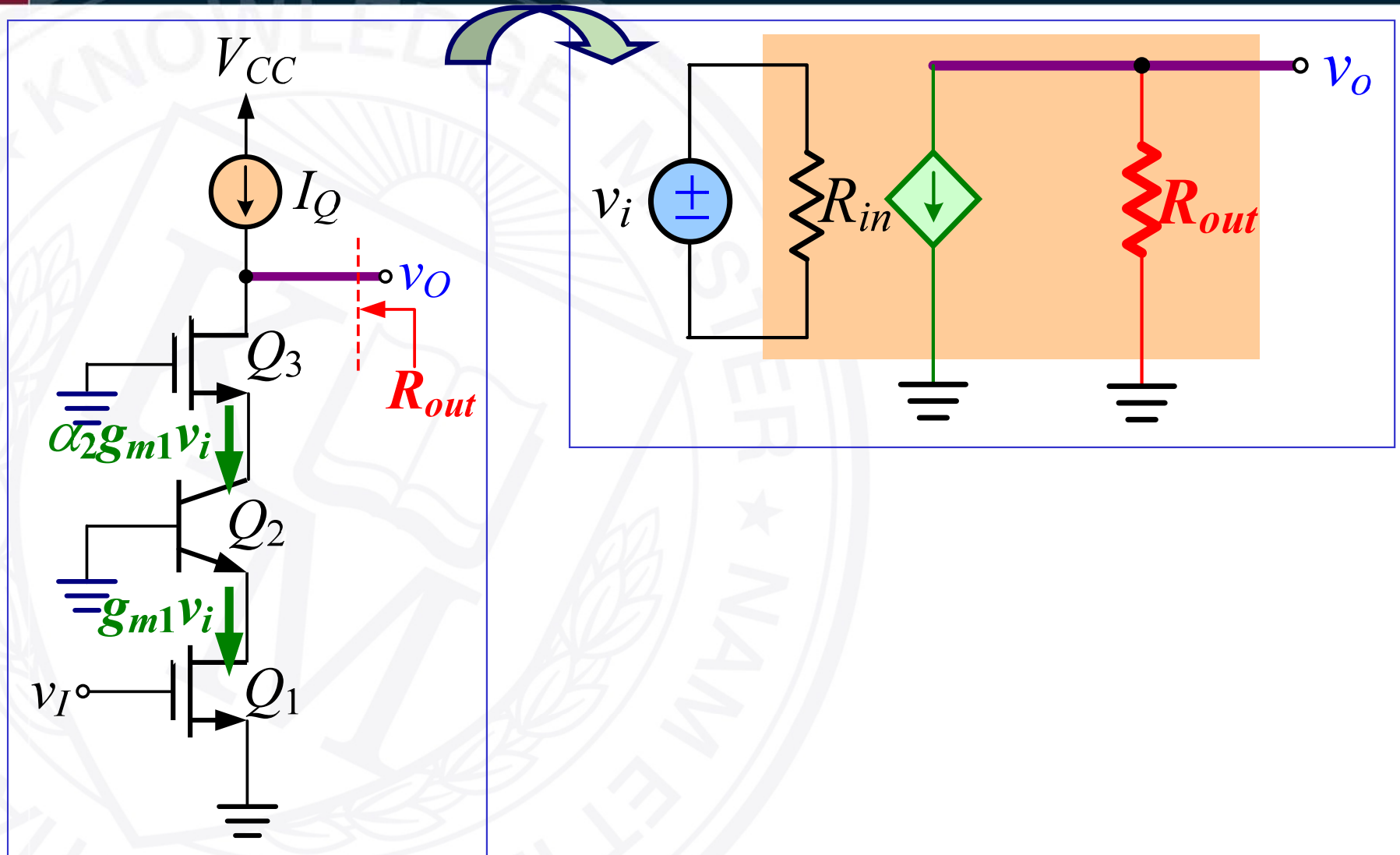
Analysis-by-Inspection



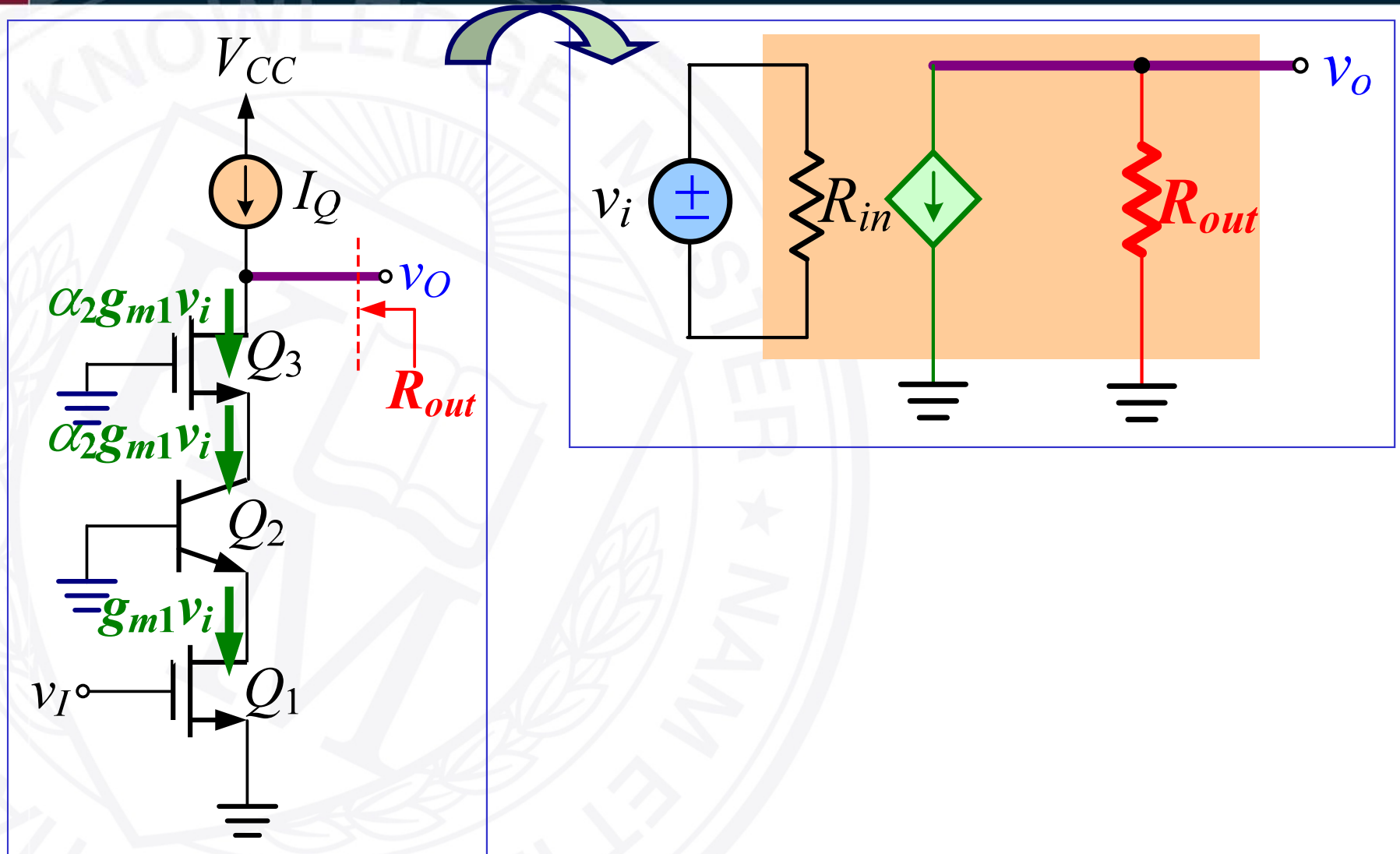
Transconductance



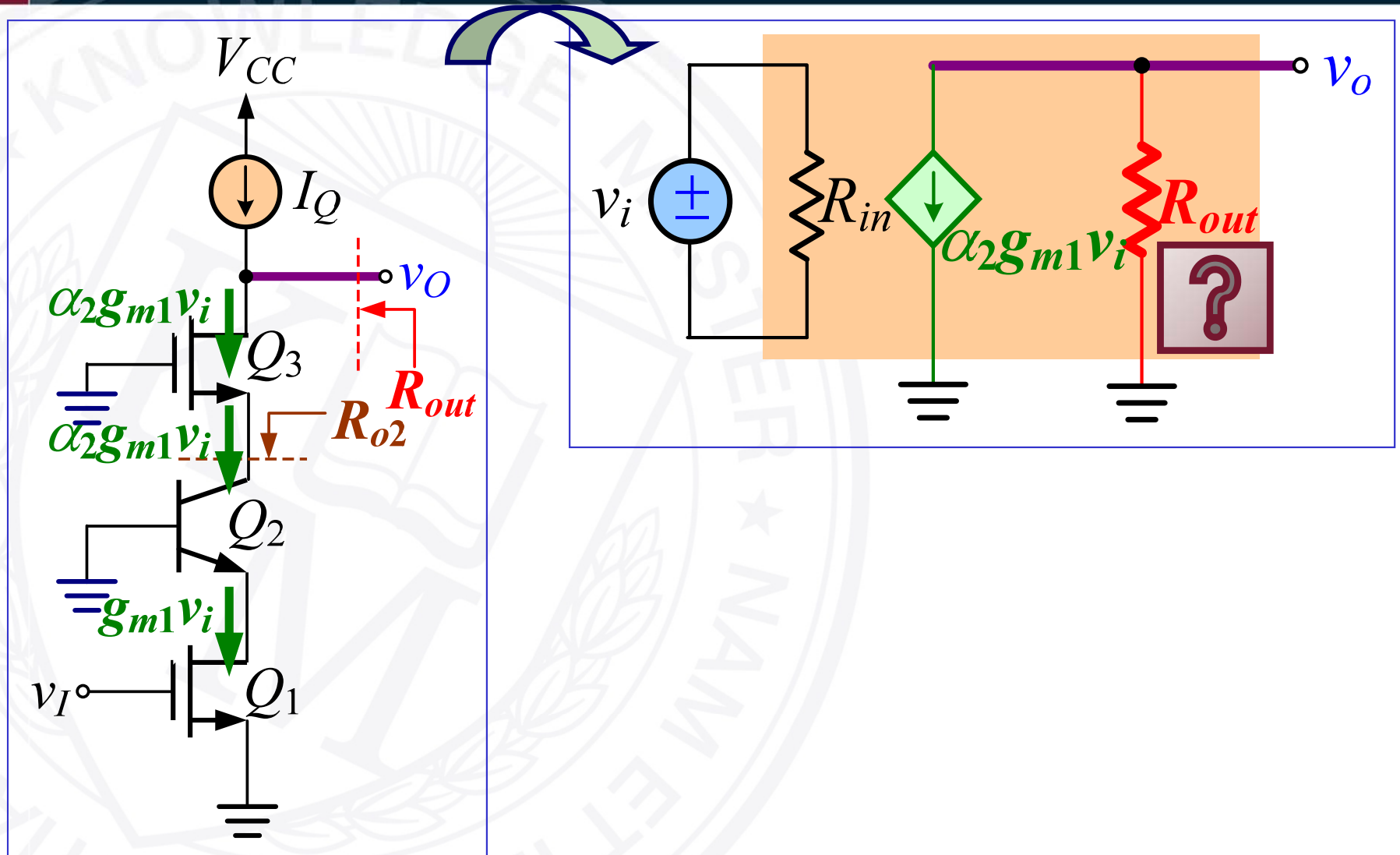
Transconductance



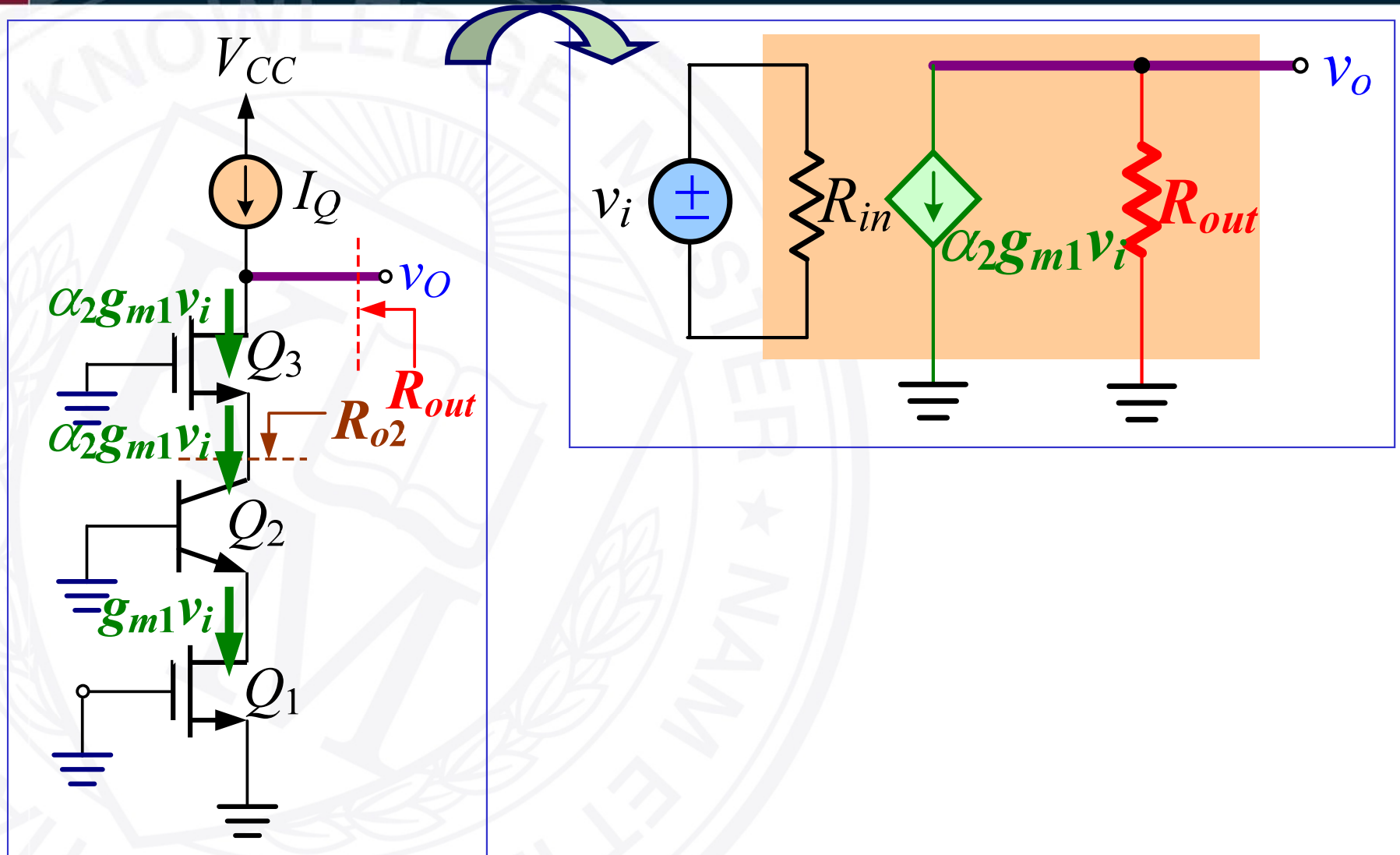
Transconductance



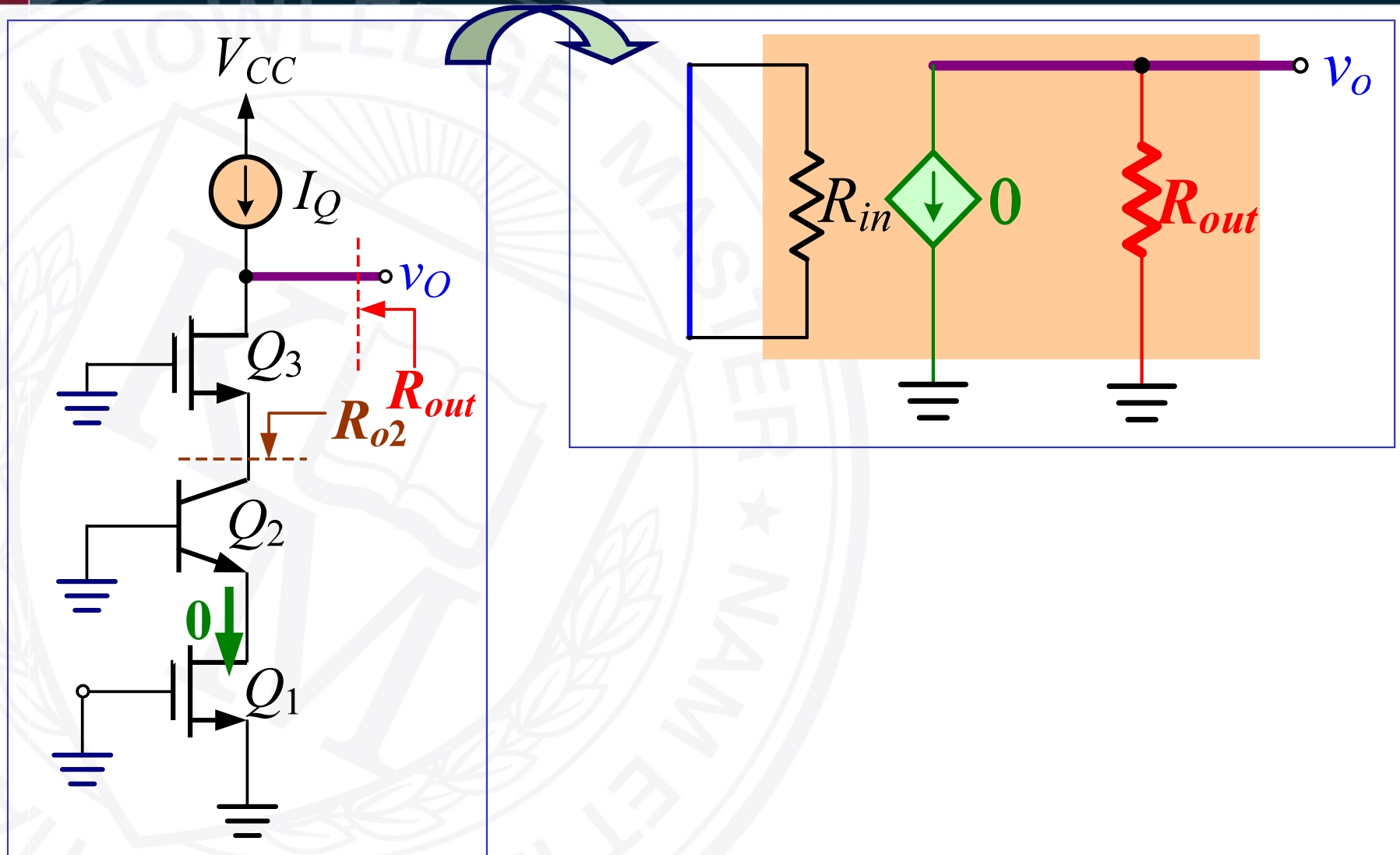
Transconductance



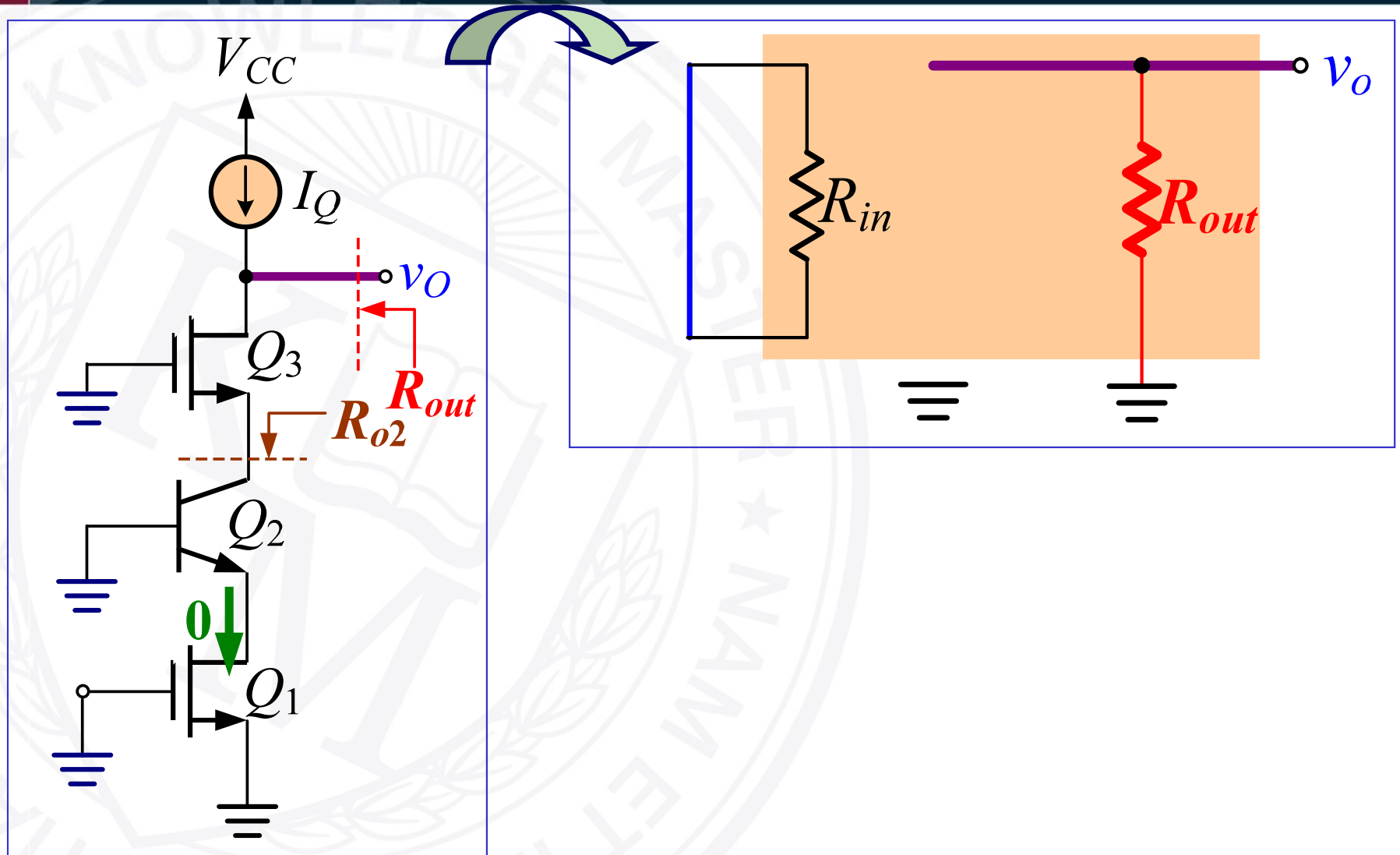
Output Resistance



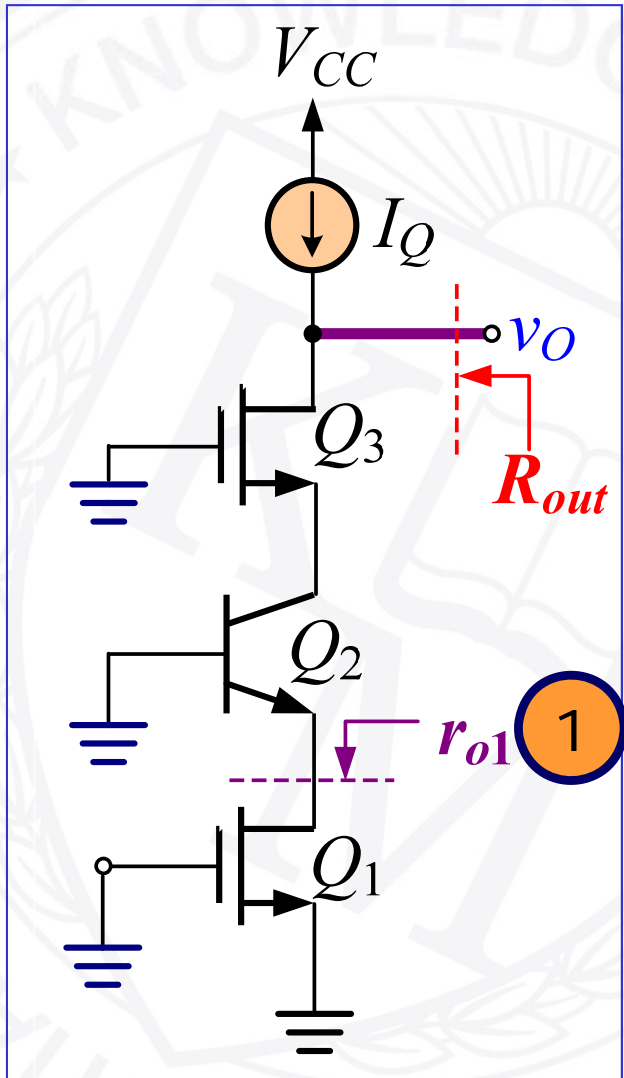
Output Resistance



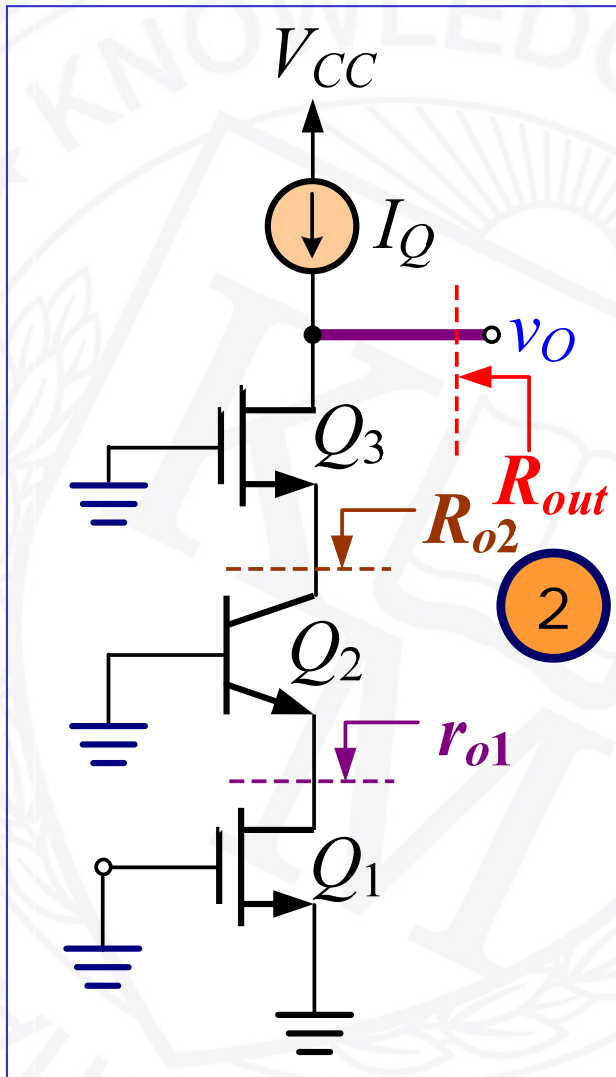
Output Resistance



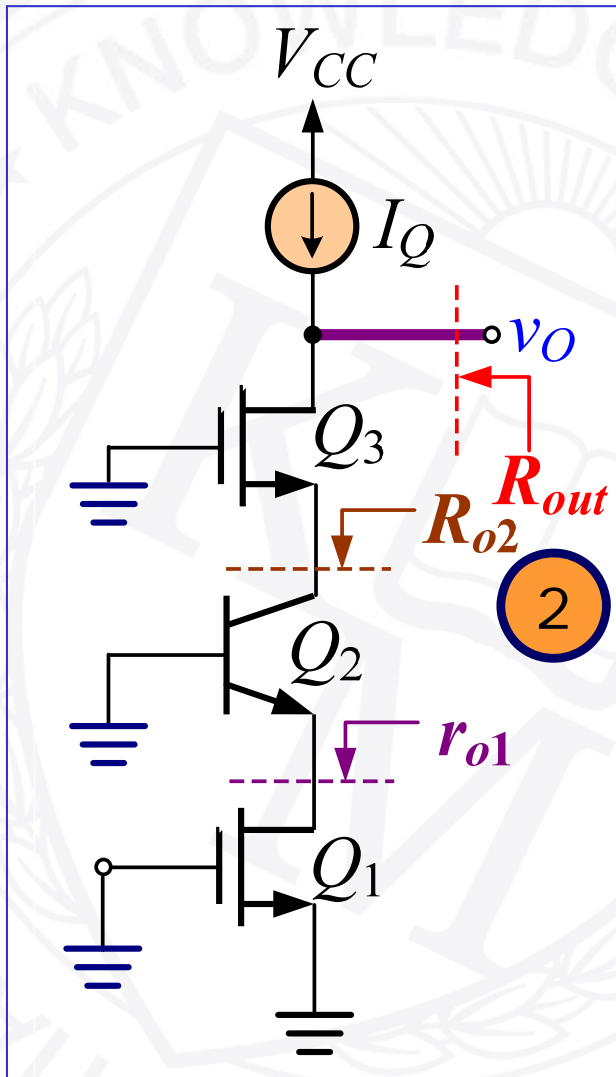
Output Resistance



Output Resistance

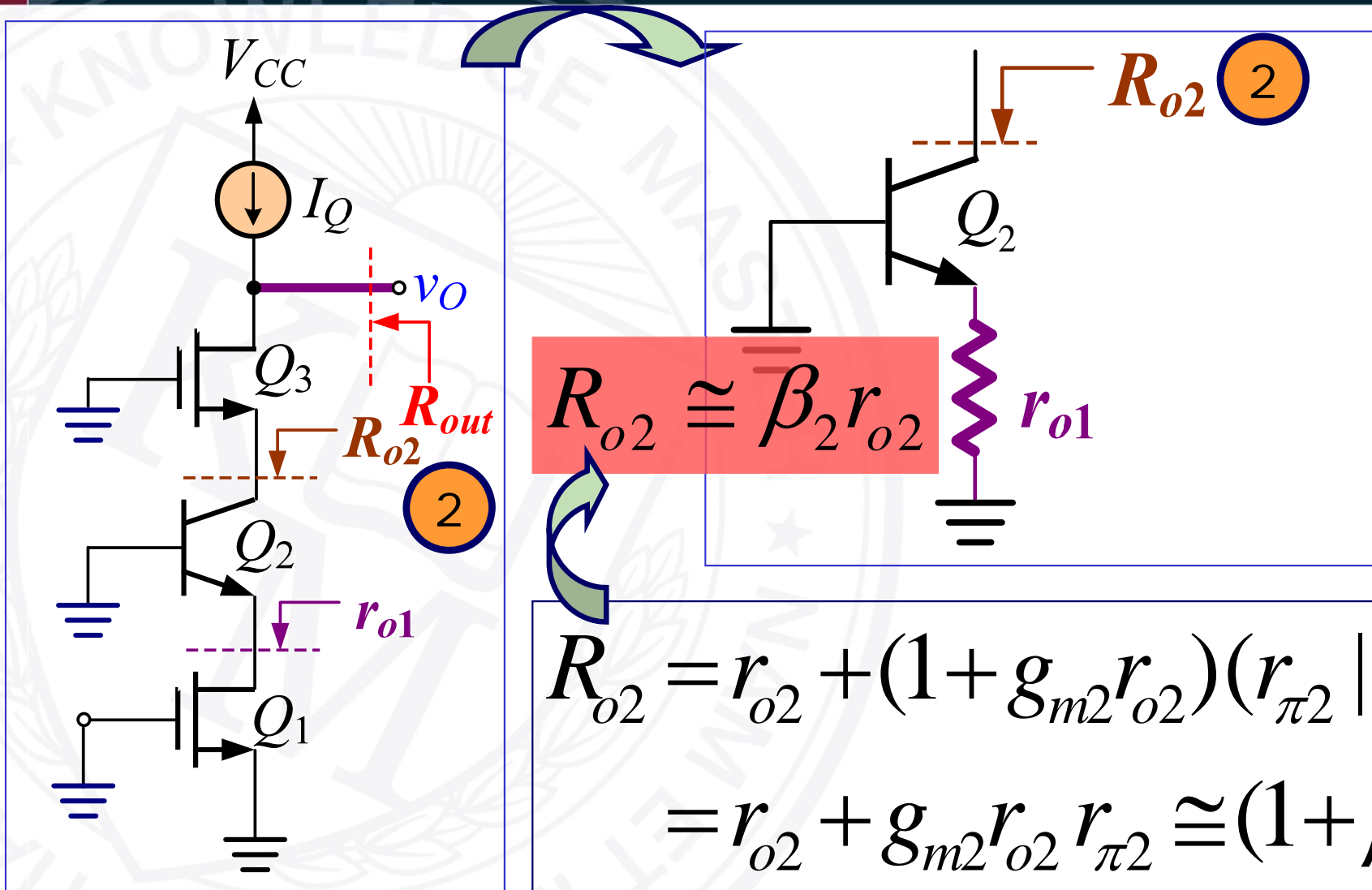


Output Resistance

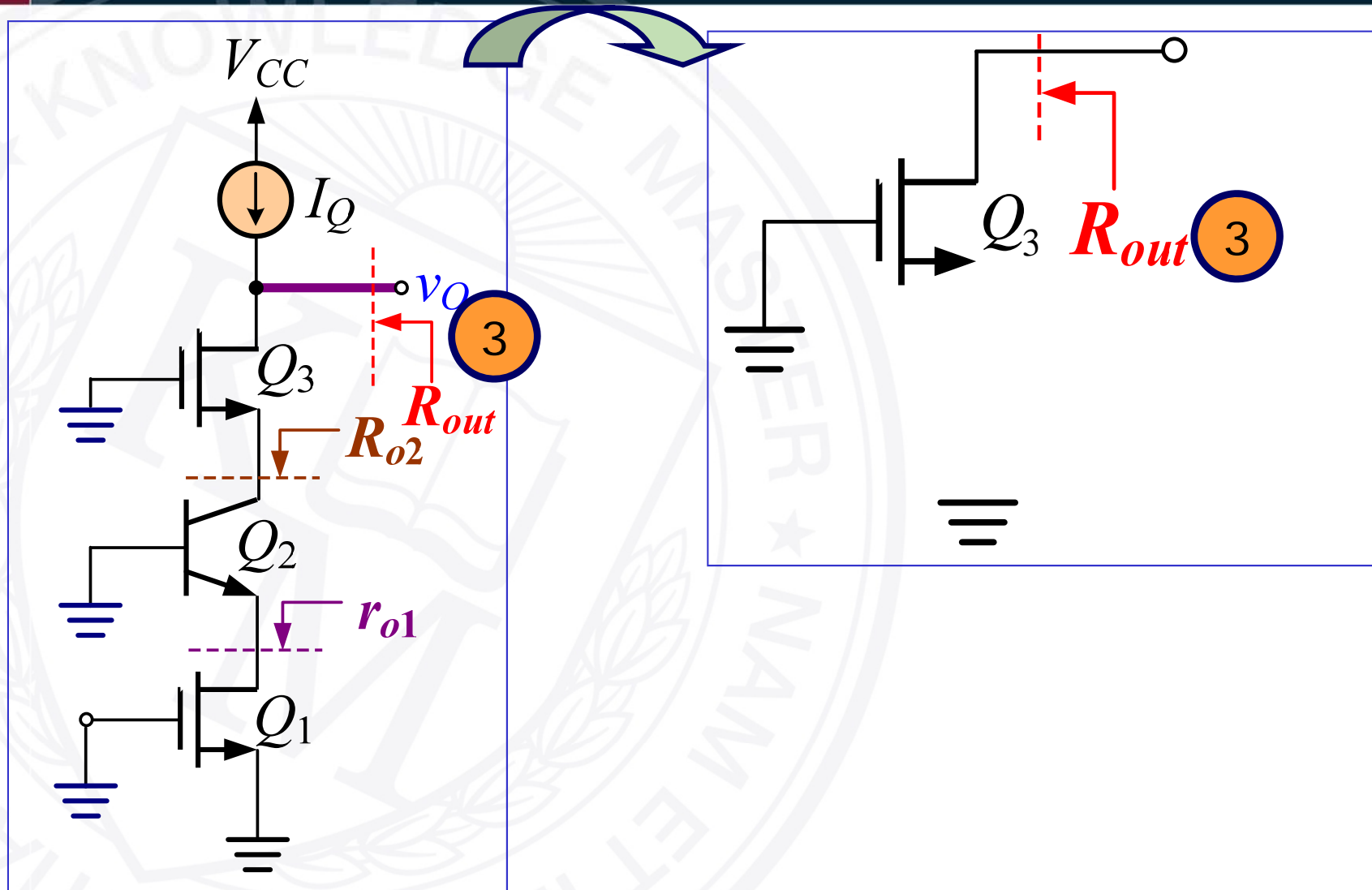


$$R_{o2} \cong \beta_2 r_{o2}$$

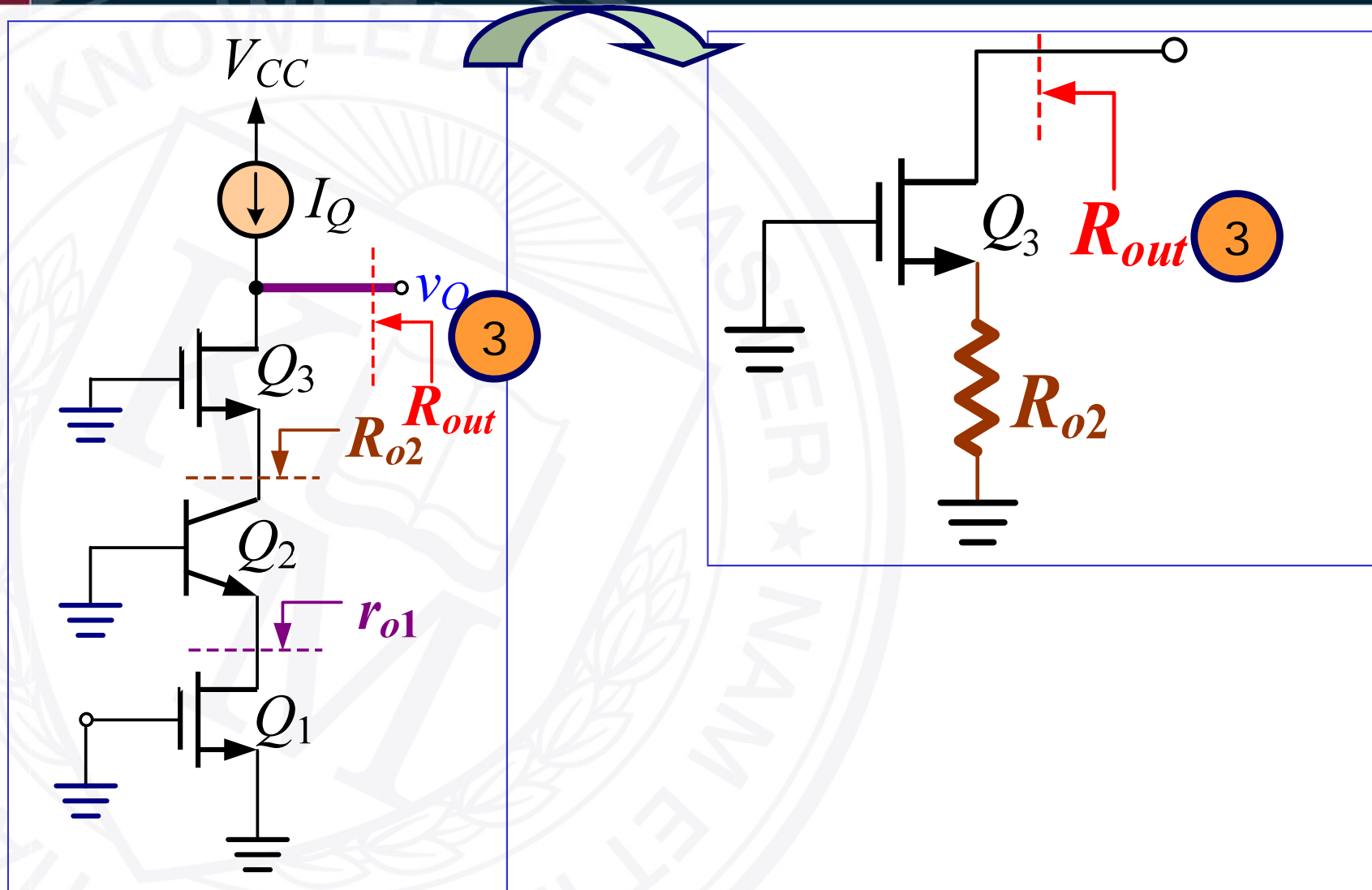
Output Resistance



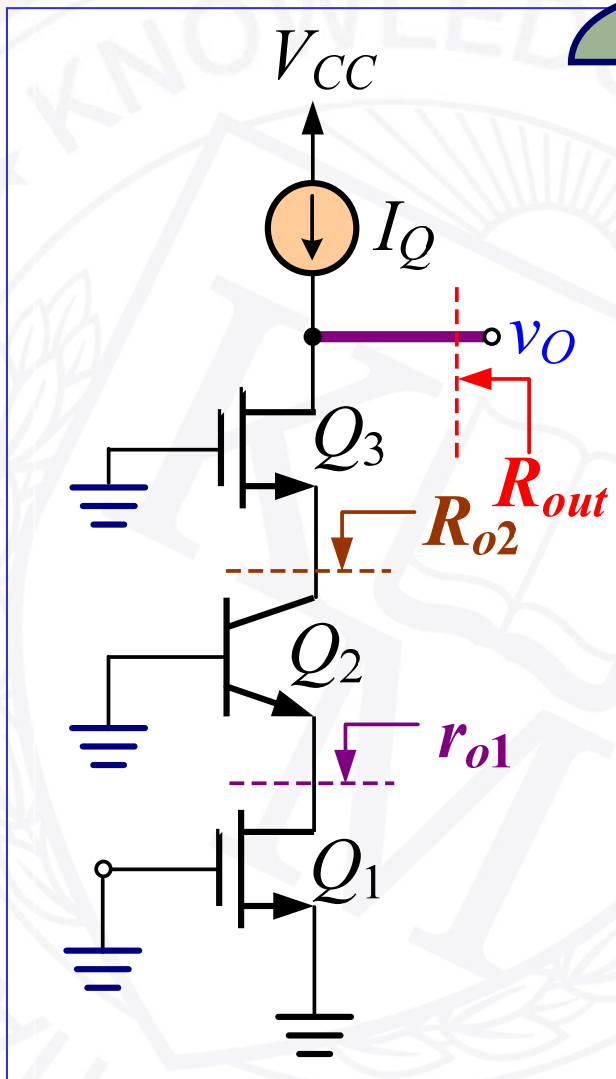
Output Resistance



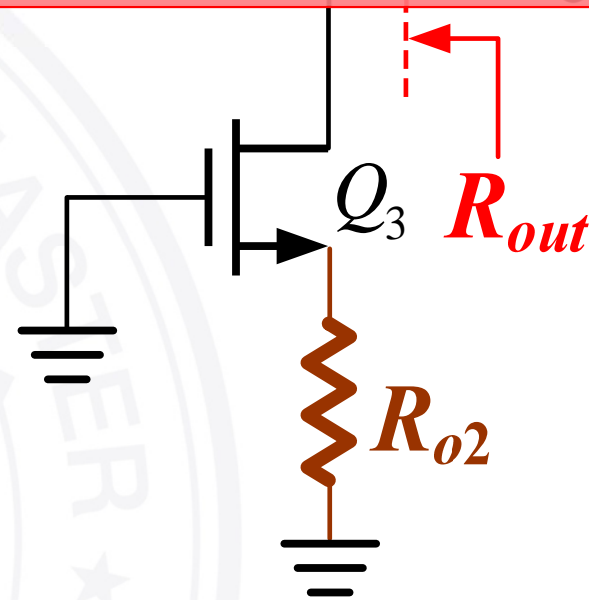
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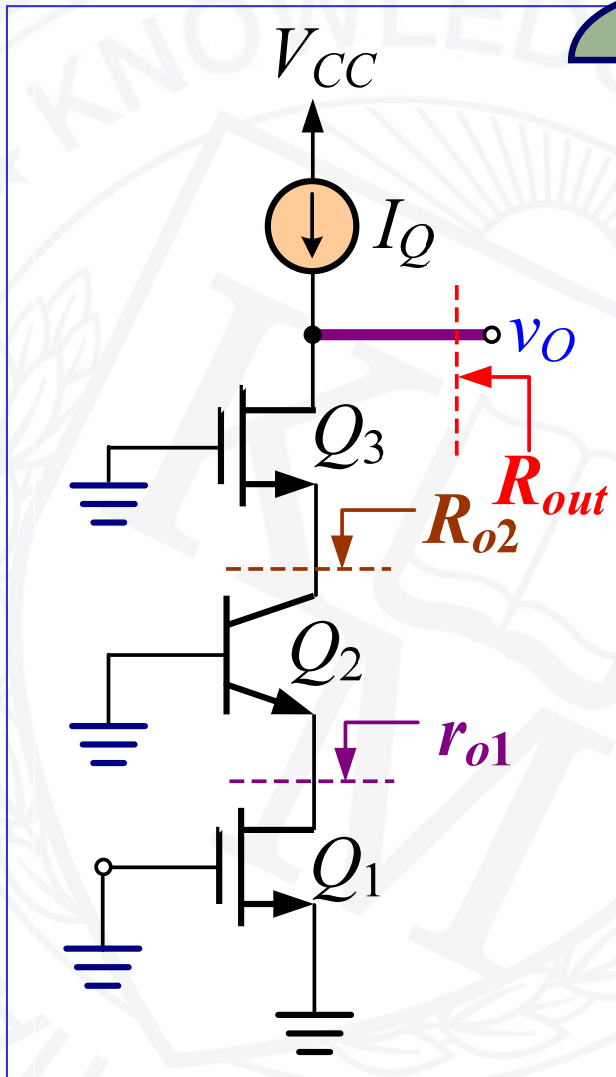
Output Resistance



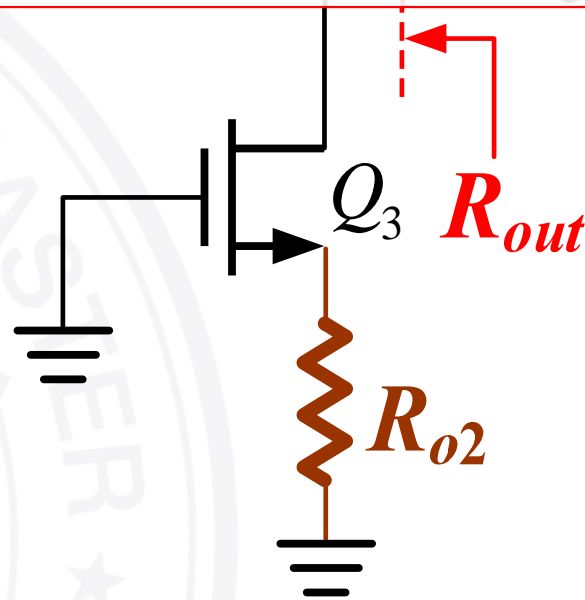
$$R_{out} = r_{o3} + (1 + \mu_3) R_{o2}$$



Output Resistance



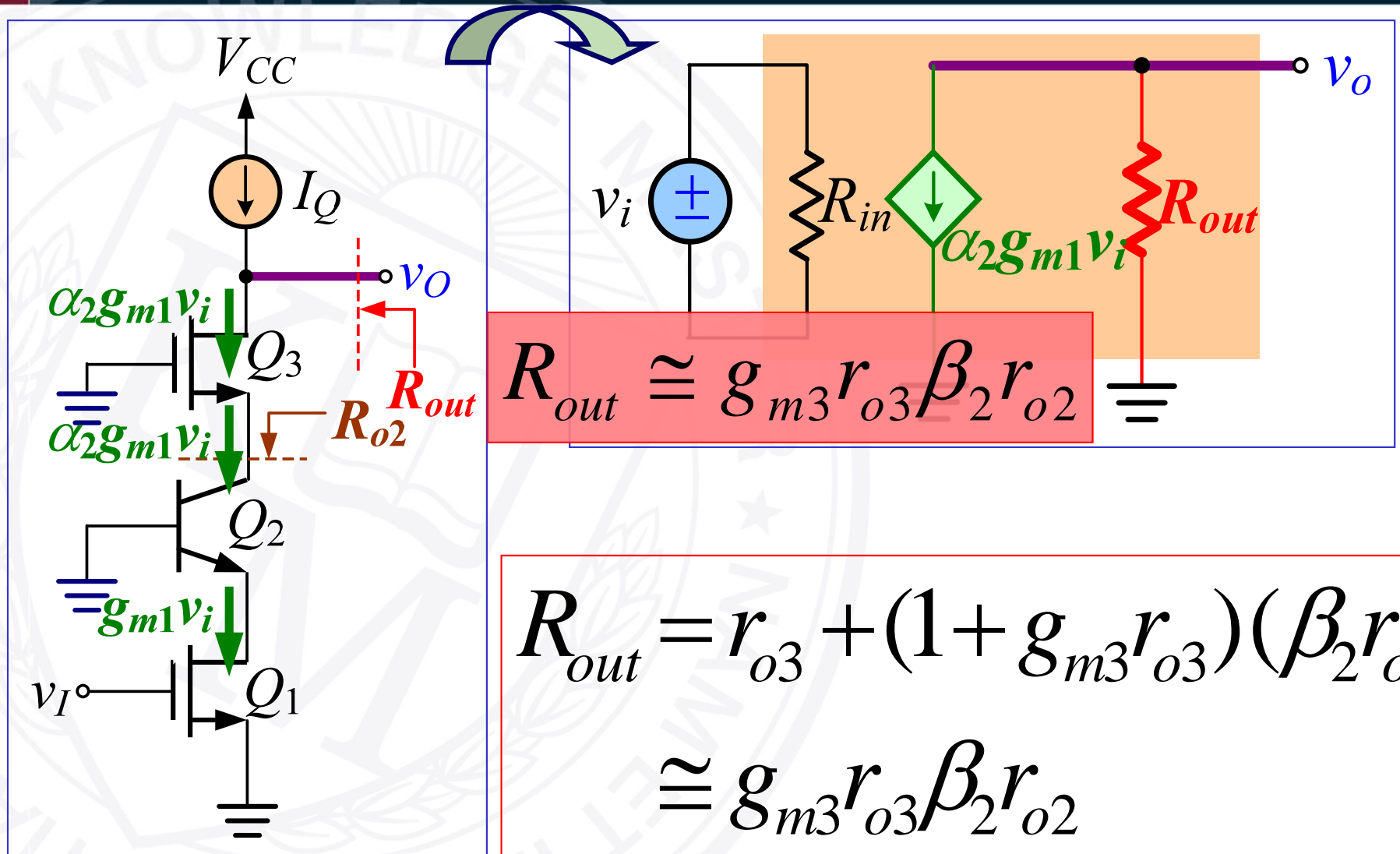
$$R_{out} = r_{o3} + (1 + \mu_3) R_{o2}$$



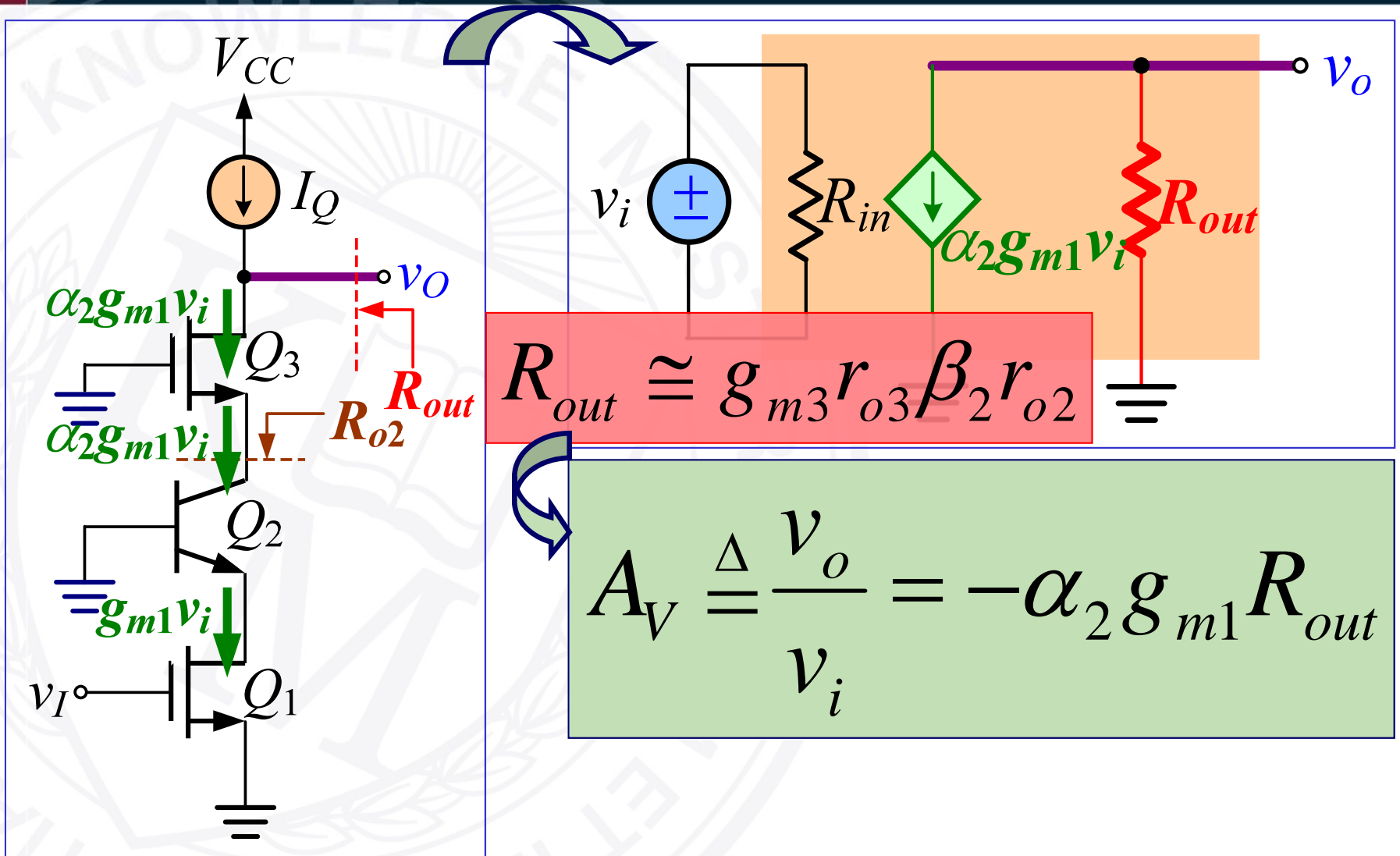
$$R_{out} = r_{o3} + (1 + g_{m3} r_{o3}) (\beta_2 r_{o2})$$

$$\cong g_{m3} r_{o3} \beta_2 r_{o2}$$

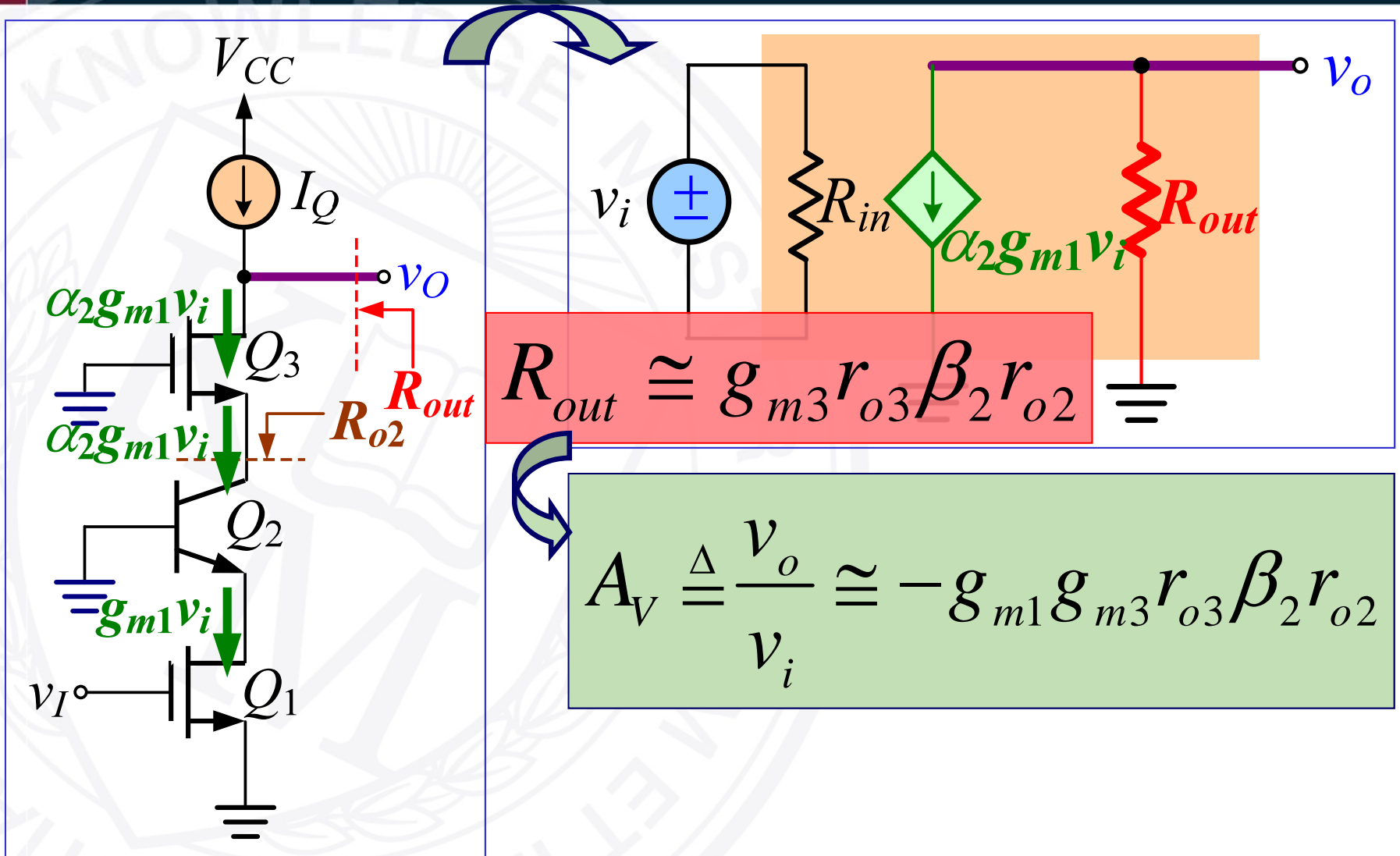
Norton Equivalent



Small-Signal Voltage Gain



Small-Signal Voltage Gain



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