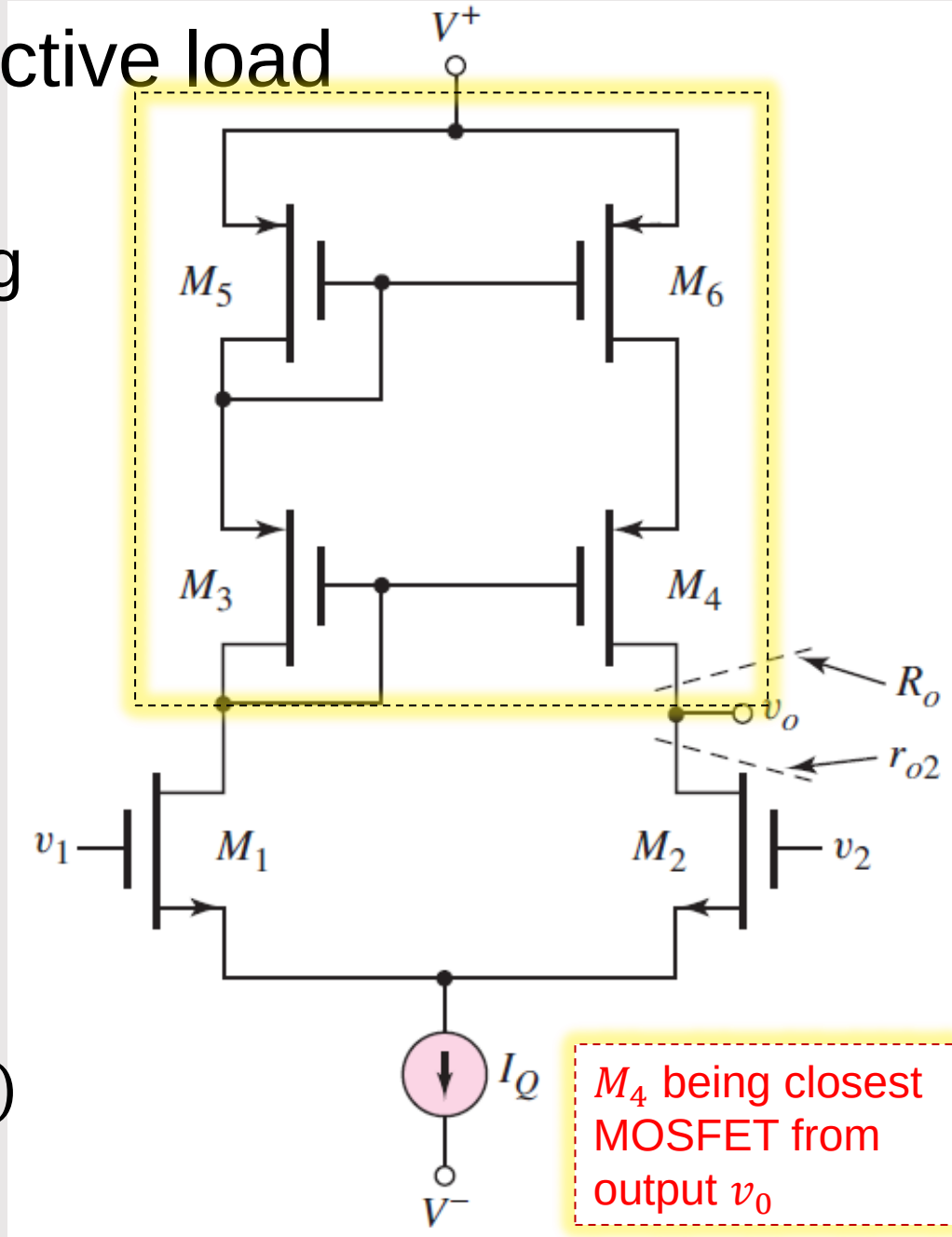
2. MOSFET Diff Amp with Cascode Active load

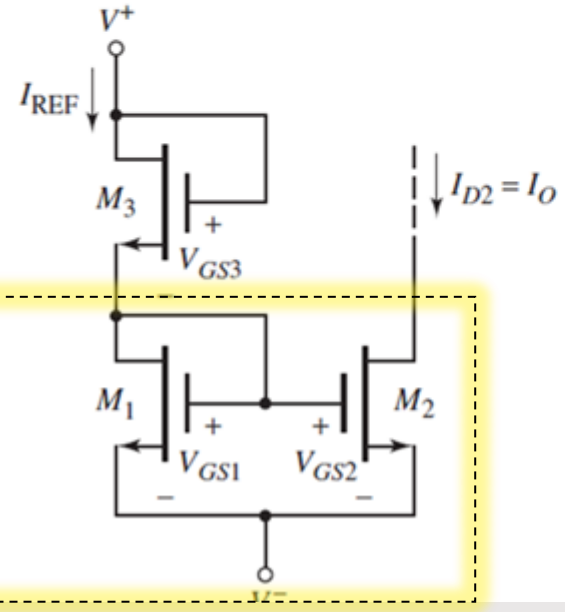
- The differential-mode voltage gain is proportional to the output resistance looking into the active load transistor.
  The voltage gain can be increased, therefore, if the output resistance can be increased.
- An increase in output resistance can be achieved by using, for example, a cascode active load.
- Cascode has $M_4, M6$ as the MOSFETs in output end of the highlighted load circuit.
- Output resistance $R_0 = r_{04} + r_{06}(1 + g_m r_{04})$



Remembering Cascode current mirror

Comparison of output resistance of Cascode MOSFET current source to that of two transistor current source:

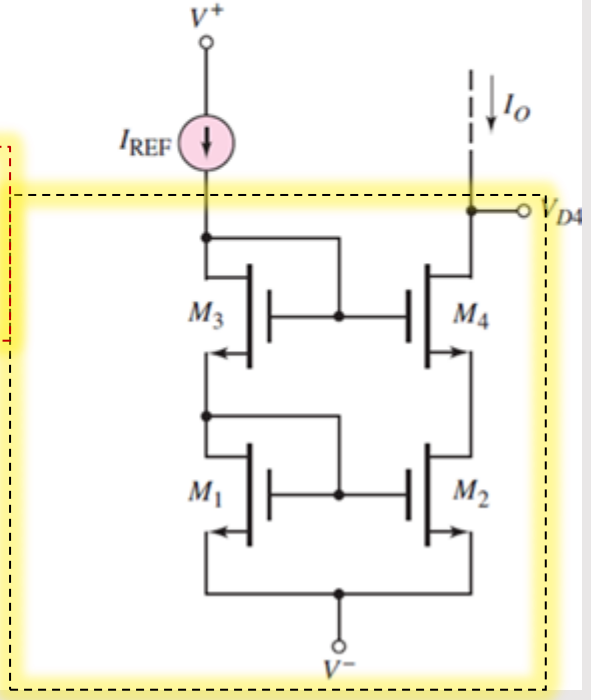
- Two transistor current source:
  Output Resistance $r_0 = \frac{1}{\lambda I_{REF}}$



Cascode MOSFET Current source

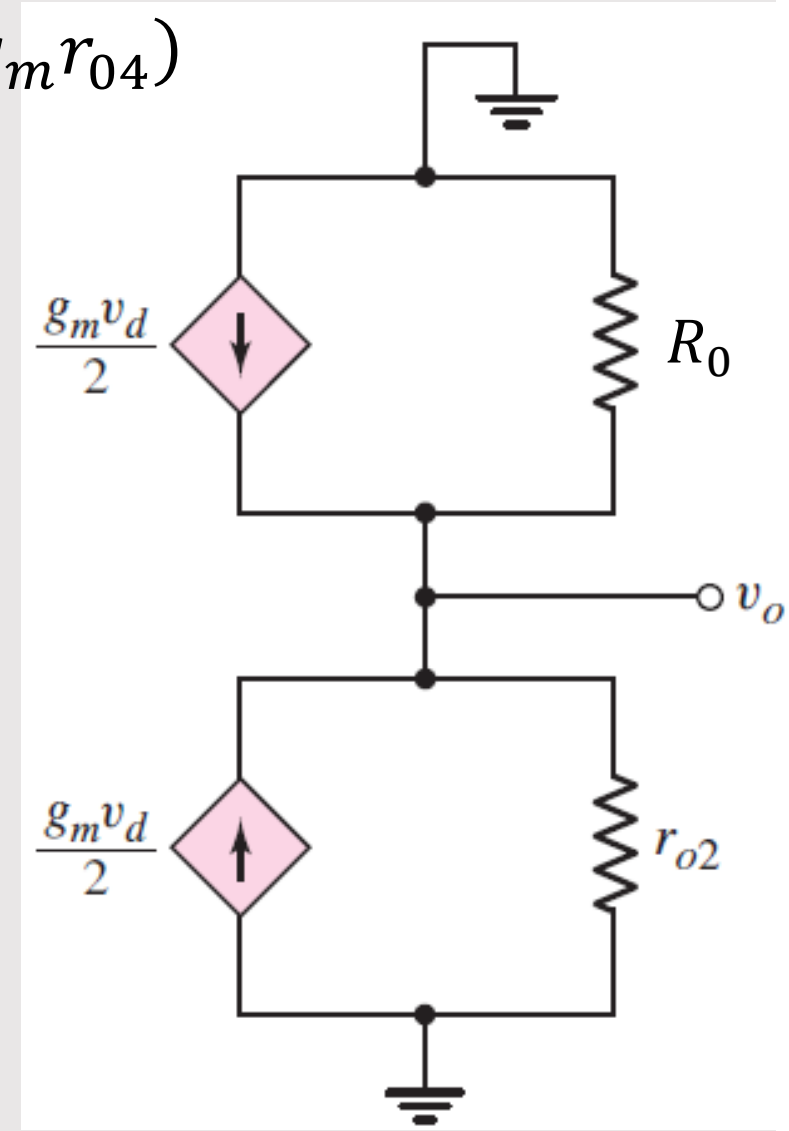
$R_0 = r_{04} + r_{02}(g_m r_{04} + 1)$

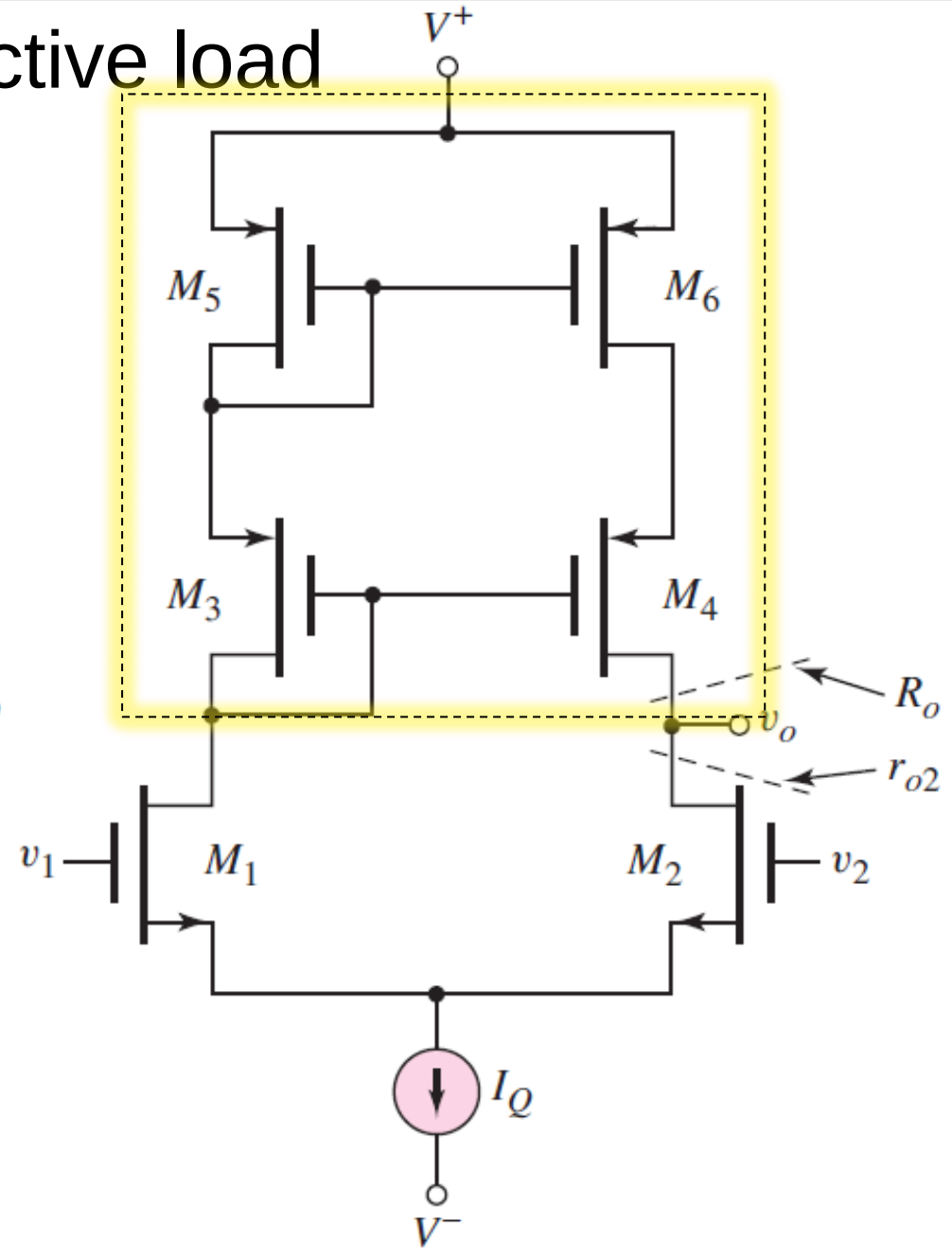
M_4 being closest MOSFET from output V_{D4}



2. MOSFET Diff Amp with Cascode Active load

- $R_0 = r_{04} + r_{06}(1 + g_m r_{04})$



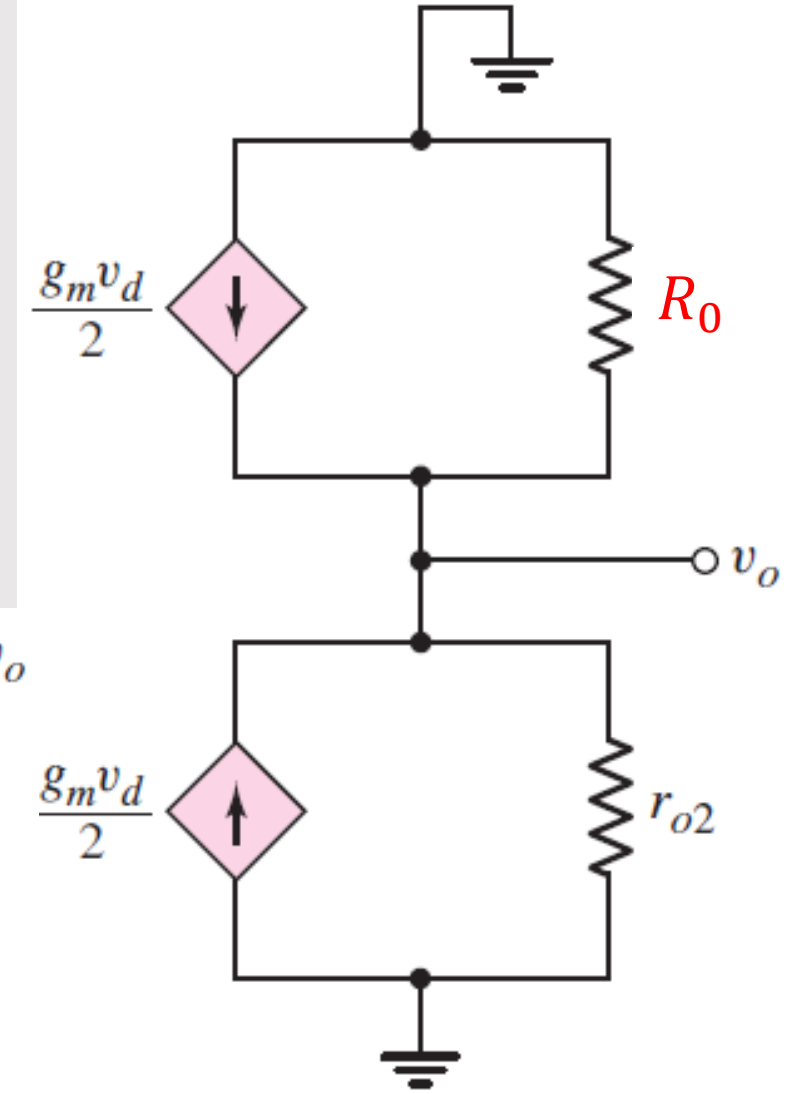


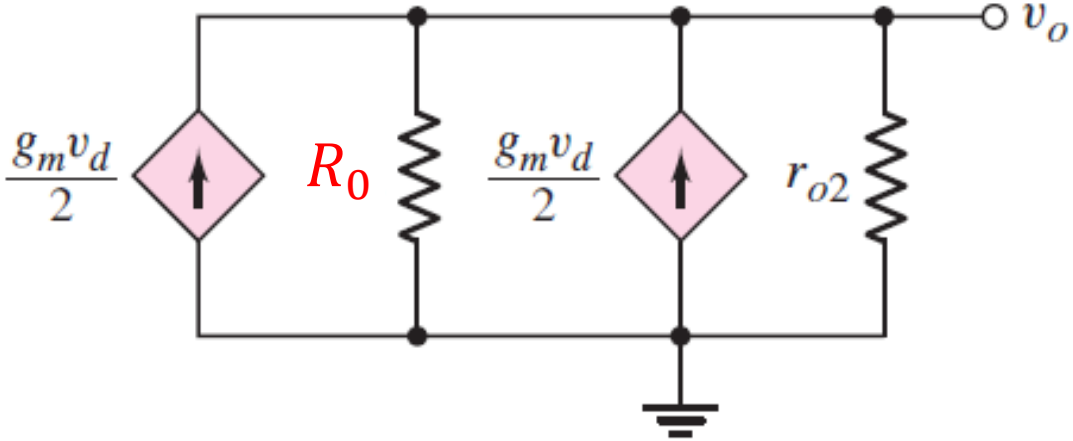
2. MOSFET Diff Amp with Cascode Active load

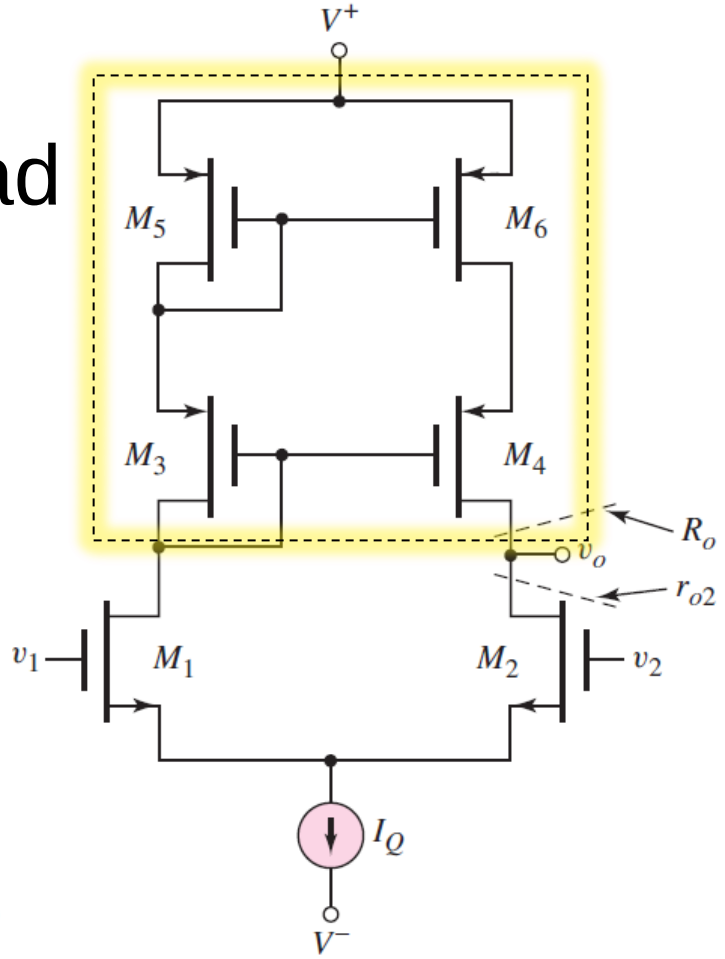
- $R_0 = r_{04} + r_{06}(1 + g_m r_{04})$
- $v_0 = i(r_{02} \parallel R_0)$

  $v_0 = 2\left(\frac{g_m v_d}{2}\right)(r_{02} \parallel R_O)$
- Small signal diff mode voltage gain:

  $A_d = \frac{v_0}{v_d} = g_m(r_{02} \parallel R_O)$







Problem: Calculate the differential-mode voltage gain of a MOSFET diff-amp with a cascode active load. Note: $(W/L)_n = 10$; $I_{DQ} = 0.1mA$; $k_n' = 80\mu A/V^2$; $V_{TN} = 0.5V$; $\lambda_n = 0.02V^{-1}$; $V_{TP} = -1V$; $k_p' = 40\mu A/V^2$; $\lambda_p = 0.02V^{-1}$;

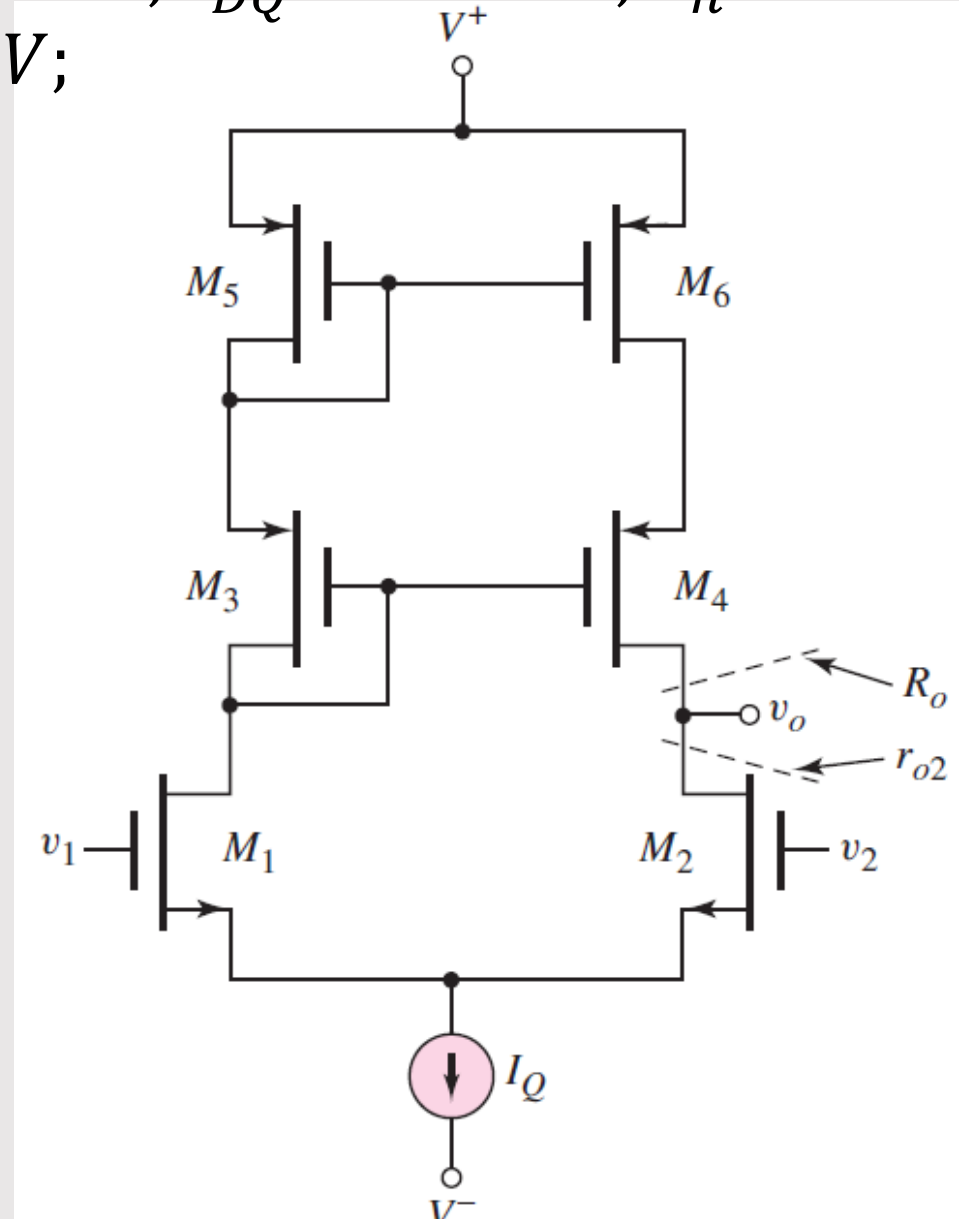
- $K_n = \frac{k_n'}{2}\left(\frac{W}{L}\right) = \frac{80\times10^{-6}}{2}(10) = 0.4 \times 10^{-3} A/V^2$
- Transconductance: $g_m = 2\sqrt{K_n I_{DQ}}$

$$= 2\sqrt{(0.4 \times 10^{-3})(0.1 \times 10^{-3})}$$

$$= 0.4mA/V$$

- Output resistance of individual transistors:

$$r_0 = \frac{1}{\lambda I_{DQ}} = \frac{1}{(0.02)(0.4m)} = 500k\Omega$$



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- $g_m = 0.4mA/V$ $\quad r_0 = 500k\Omega$
- Cascode active load output resistance:

$$R_0 = r_{04} + r_{06}(1 + g_m r_{04})$$

$$= 500k + 500k\big(1 + 0.4m(500k)\big)$$

$$= 500k + 500k(201)$$

$$= 101000k = 101M\Omega$$

Diff mode voltage gain: $A_d = \frac{v_0}{v_d} = g_m(r_{02} \parallel R_O)$

$$A_d = 0.4m(500k \parallel 101000k) = 200$$