Modified Wilson current source

Problem: All transistors in the MOSFET modified Wilson current source are identical. The parameters are: $V_{TN} = 1\,V$; $K_n = 0.2\,mA/V^2$, and $\lambda = 0$. If $I_{REF} = 250\,\mu A$, determine I_O and V_{GS} for each transistor. (Ans. *I*O = *I*REF = 250 μA, *VGS* = 2.12 V)

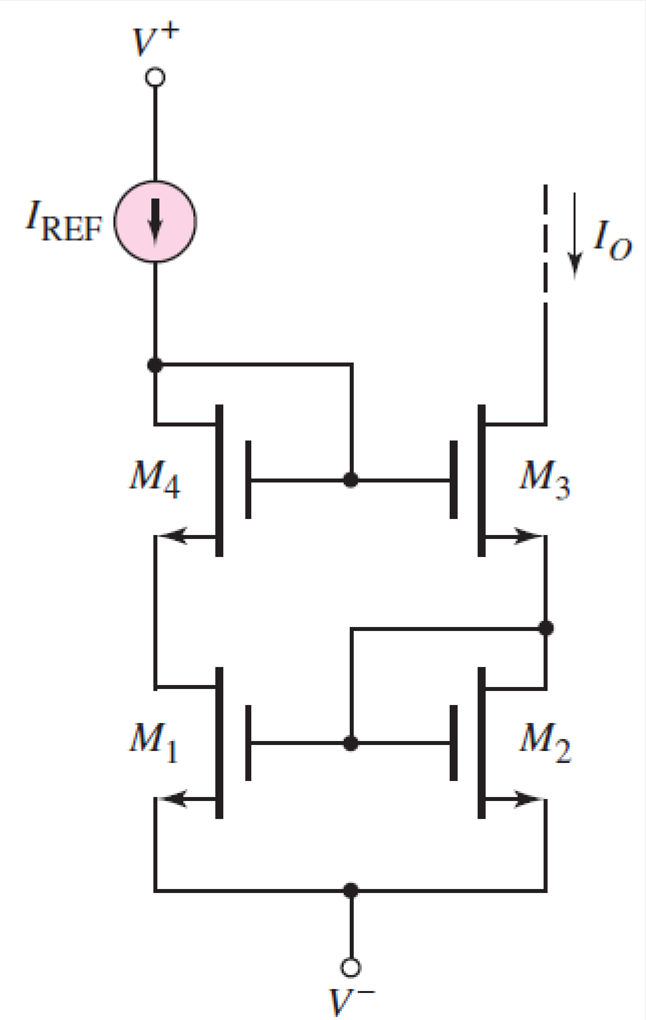
- Modified Wilson current source:

  $$I_{REF} = I_O = 250\mu A$$

- $I_D = I_{REF} = K_n(V_{GS} - V_{TN})^2(1 + \lambda V_{DS})$

  $$250\mu = 0.2m(V_{GS} - 1)^2(1 + 0)$$

- $V_{GS} = 2.12V$
- Since all drain currents are same, All have same K_n, V_{TN} values, therefore

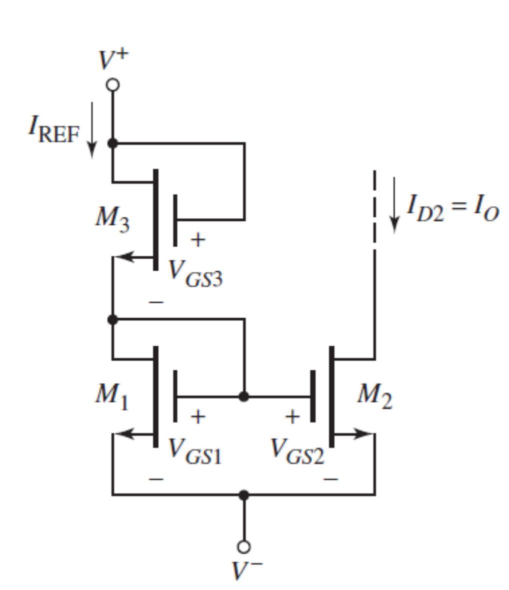


Two transistor current source and Cascode current sources

Problem: Two transistor current source and Cascode current sources are such that: $I_{REF} = I_0 = 100\mu A$ and $\lambda = 0.01V^{-1}$ and $g_m = 0.5mA/V$. Compare output resistances of both the current source circuits

- Two transistor current source: Output Resistance

$$r_0 = \frac{1}{\lambda I_{REF}} = \frac{1}{0.01\,(100\times10^{-6})} = 1\text{M}\Omega$$



Note: output resistance of identical MOSFETS are

$$r_{02} = r_{04} = r_0 = 1\text{M}\Omega$$

(output resistance from two transistor current source also)

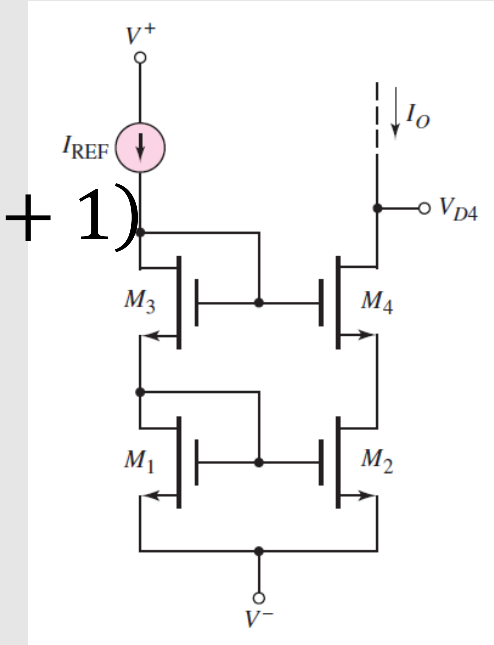
Cascode current source:

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

$$= 1M + 1M(0.5m(1M) + 1)$$

$$= 1M + 501M$$

$$= 502M\Omega$$



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

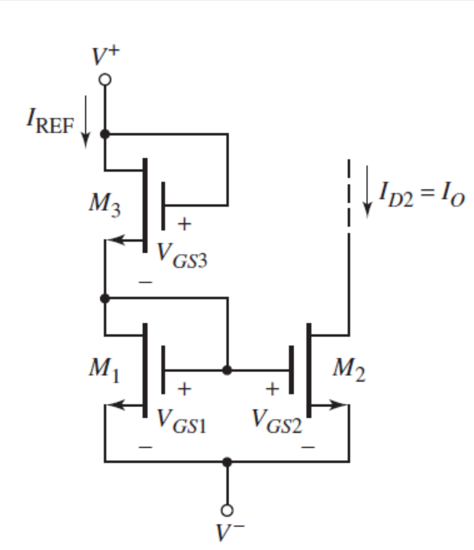
- Two transistor current source:

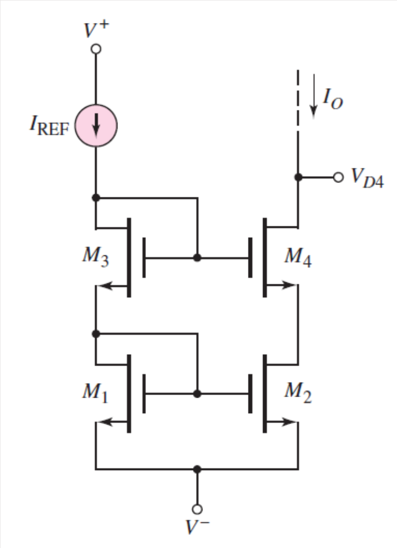
  Output Resistance $r_0 = \dfrac{1}{\lambda I_{REF}}$

Cascode MOSFET Current source

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

- Output resistance of Cascode is much larger than basic two transistor circuit. Also cascode is more stable against variations in output voltages as $dI_0 \propto 1/R_0$





MOSFET
Differential Amplifier with Basic current Mirror

Problem: With bias current $I_Q = 0.587mA$(as found before), and with $\lambda = 0.01V^{-1}$ for M_4 MOSFET, $K_{n1} = K_{n2} = 0.1mA/V^2$ and $K_{n3} = K_{n4} = 0.3mA/V^2$, find differential mode voltage gain A_d, Common-mode voltage gain A_{cm} , and CMRR for the given DiffAmp

- For the current mirror(M3 and M4), output resitance at M4:

$$R_o = \frac{1}{\lambda I_Q} = \frac{1}{(0.01)(0.587\times10^{-3})} = 170k\Omega$$

With $I_{DQ} = \frac{I_Q}{2}$

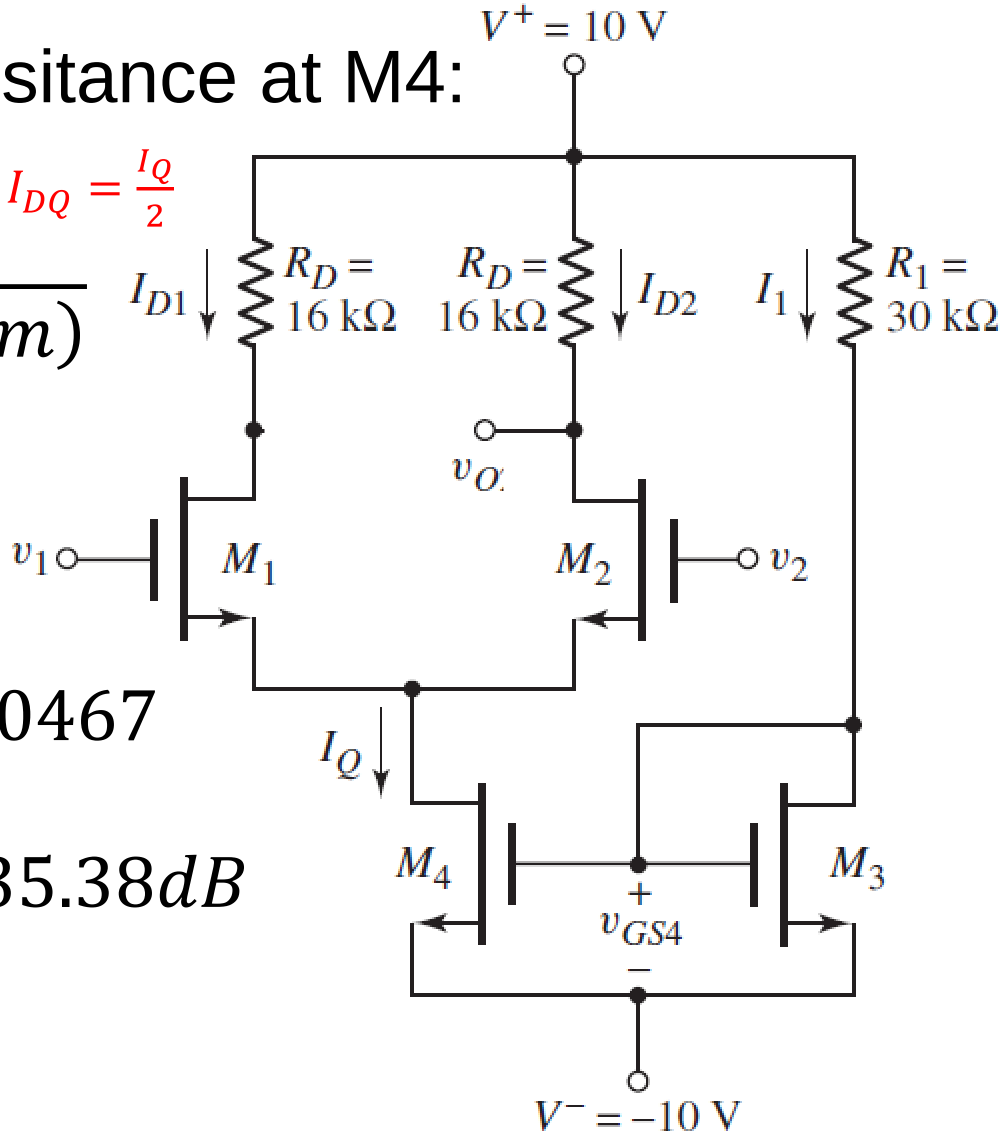
- $g_m = 2\sqrt{K_n I_{DQ}} = \sqrt{2K_n I_Q} = \sqrt{2(0.1m)(0.587m)}$

$$= 0.3426\, mA/V$$

$$A_d = \frac{g_m R_D}{2} = 0.3426m \times \frac{16k}{2} = 2.741$$

$$A_{cm} = -\frac{g_m R_D}{2g_m R_o + 1} = -\frac{0.3426m\times16k}{2(0.3426m)(170K)+1} = -0.0467$$

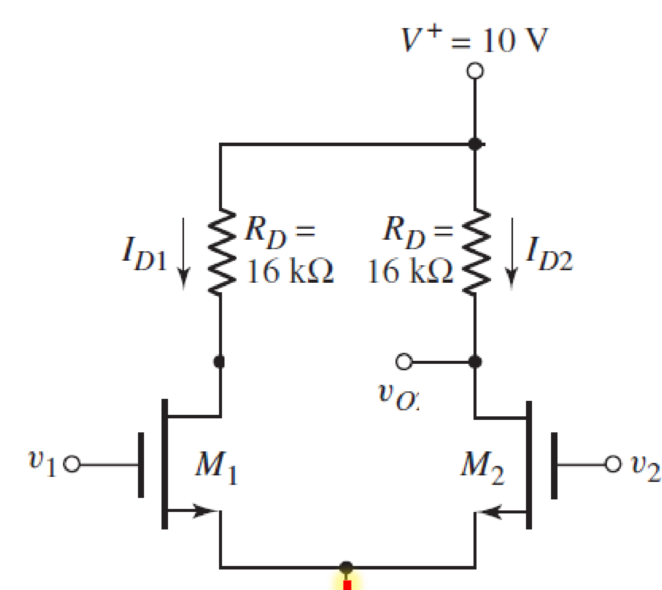
$$CMRR_{dB} = 20\log_{10}\left|\frac{A_d}{A_{cm}}\right| = 20\log_{10}\left|\frac{2.741}{0.0467}\right| = 35.38dB$$

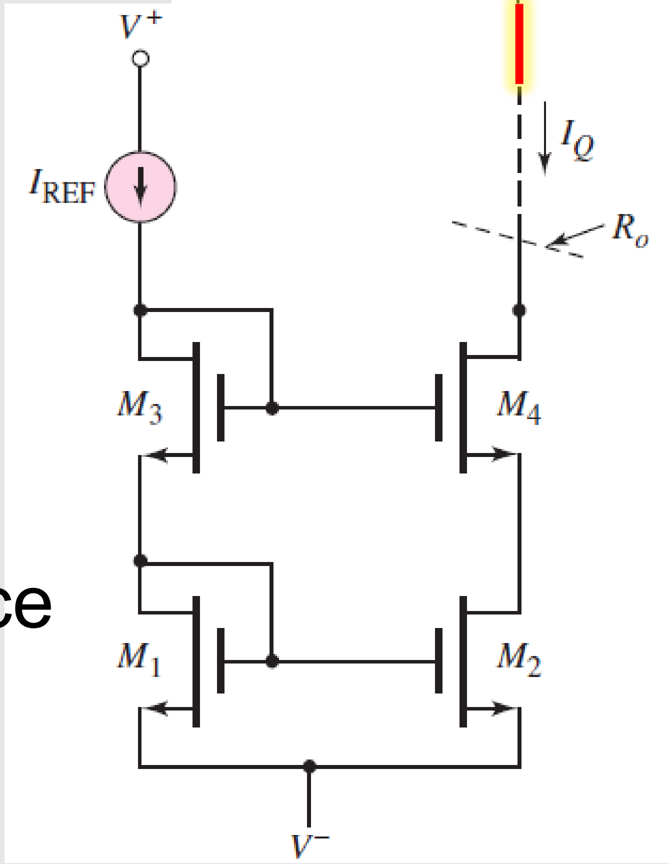


MOSFET
Differential Amplifier with cascode current mirror

Increase output resistance of current ... Diff-amp

- Using Cascode current mirror:
  $R_0 = r_{04} + r_{02}(1 + g_m r_{o4})$ with $r_{02} = r_{04} = 170k\Omega$
- $R_0 > 20M\Omega$ (several times over R_o of two MOSFET current source)
- $A_d = \frac{g_m R_D}{2}$ remains the same
- $A_{cm} = -\frac{g_m R_D}{2 g_m R_o + 1}$ decreases drastically
- $CMRR_{dB} = 20 \log_{10} \left| \frac{A_d}{A_{cm}} \right|$ will also be far greater
- Hence it is necessary to improve the current source's output resistance to increase performance of diff-amp





MOSFET
Differential Amplifier with cascode active load

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

- $g_m = 0.4mA/V \qquad r_0 = 500k\Omega$
- 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: $A_d = \frac{v_0}{v_d} = g_m(r_{02} \parallel R_O)$

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