Lecture 25

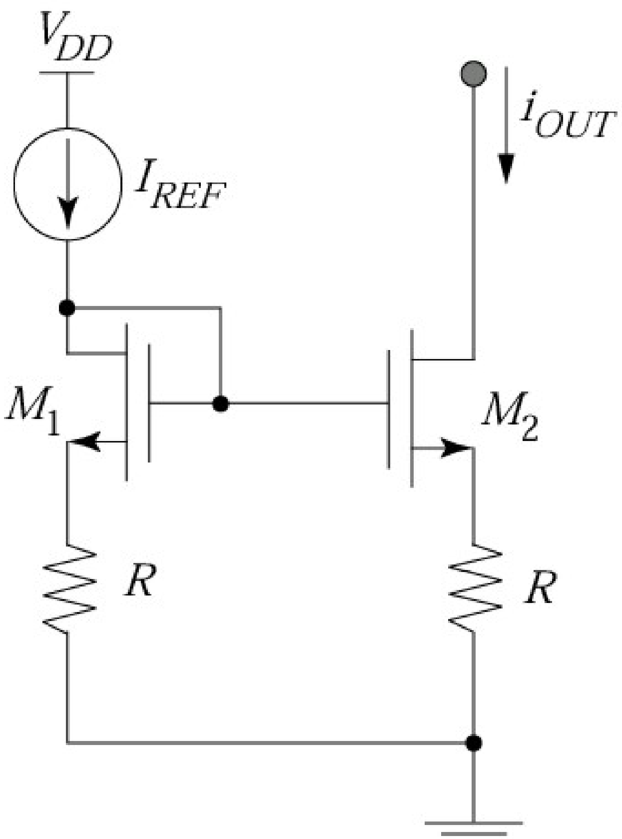
- Last time:
  - Cascode: merged CS/CG cascade
  - Cascode current supplies
- Today :
  - Cascode transconductance amplifier: full design

Improved Current Sources

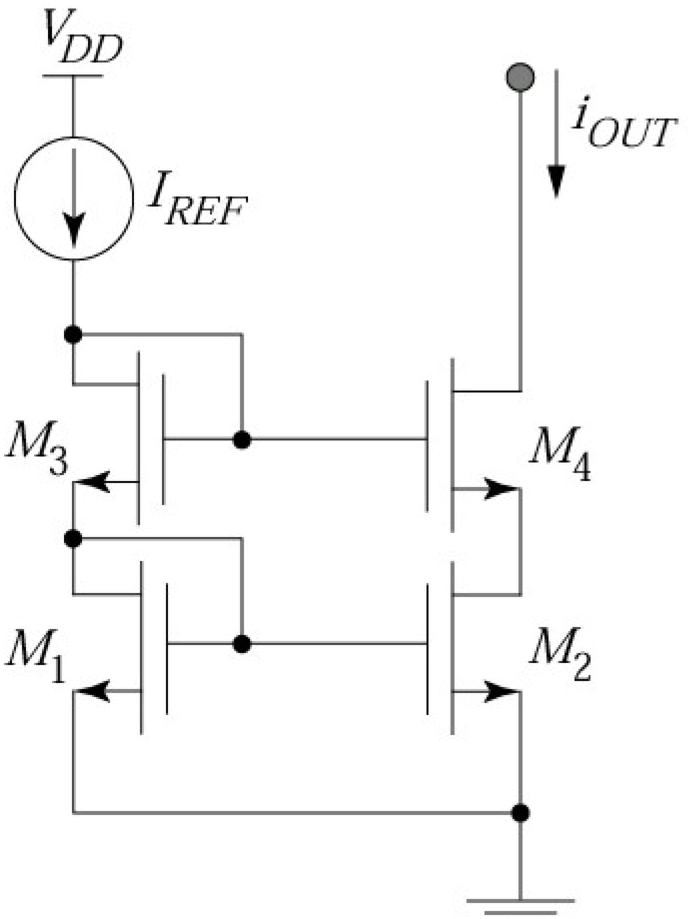
Goal: increase r_{oc}

Approach: look at *amplifier* (?) output resistance results

… to see topologies that boost resistance



Cascode (or Stacked) Current Source



Insight: V_{GS2} = constant AND
V_{DS2} = constant

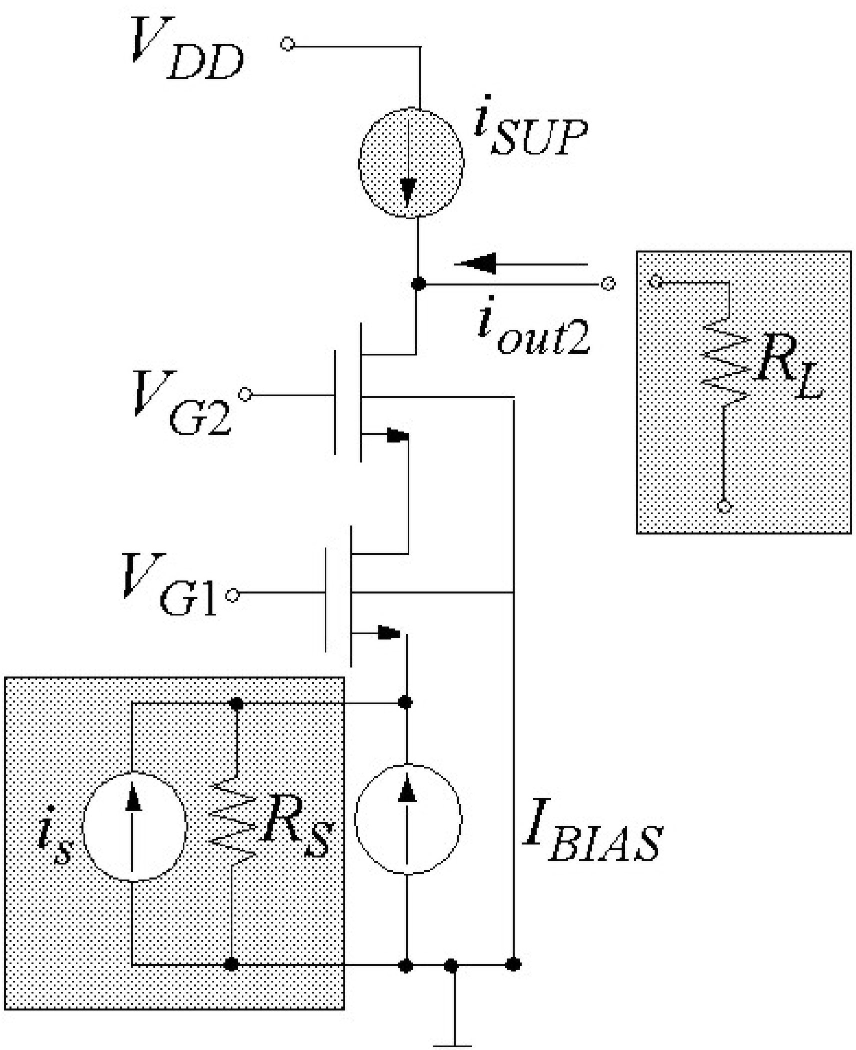
Small-Signal Resistance r_{oc}:

Drawback of Cascode *I*-Source

Minimum output voltage for all transistors saturated:

$$V_{OUT,MIN} = V_{DS4,SAT} + V_{S4} = V_{DS4,SAT} + V_{GS2}$$

CG Cascade: Sharing a Supply



First stage has no current supply of its own → its output resistance is modified

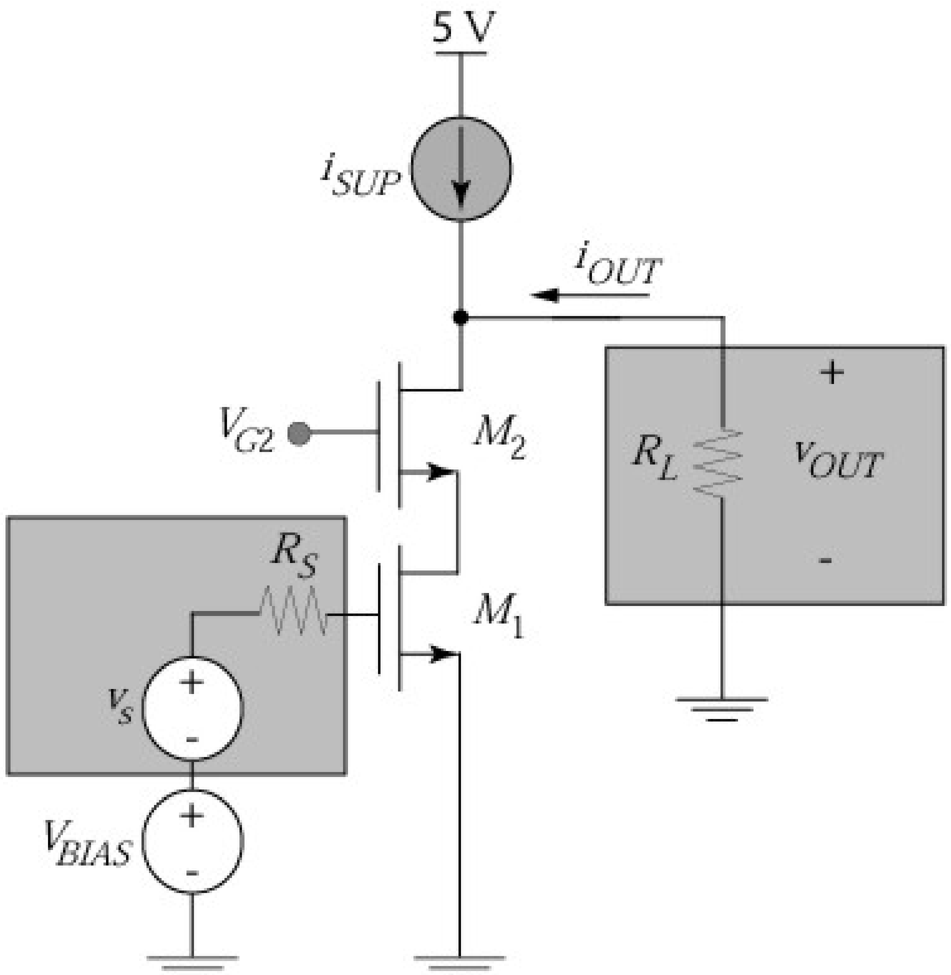
Amplifier Topology

Goals: R_{in} and R_{out} should be maximized

Common source – common gate cascode makes sense

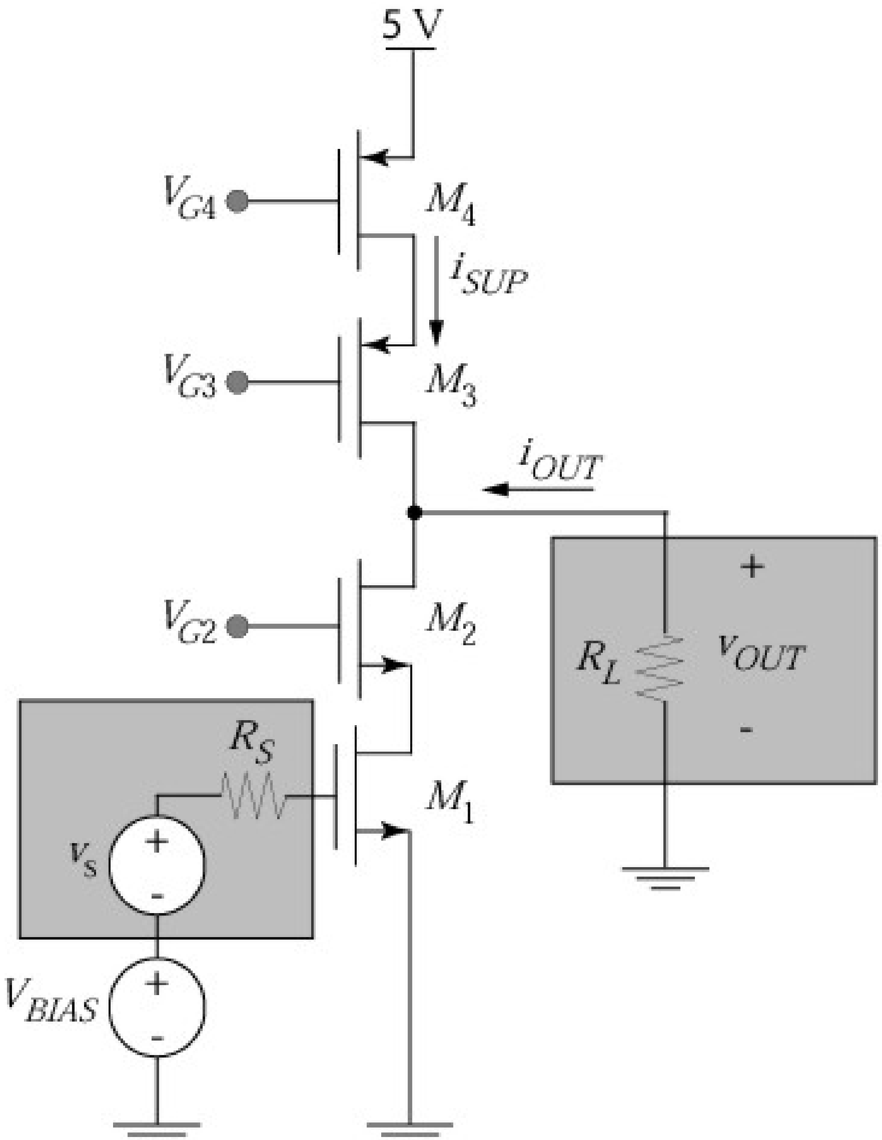
Share the current supply

Amplifier Schematic



Note that the backgate connection for M_2 is not specified: ignore g_{mb}

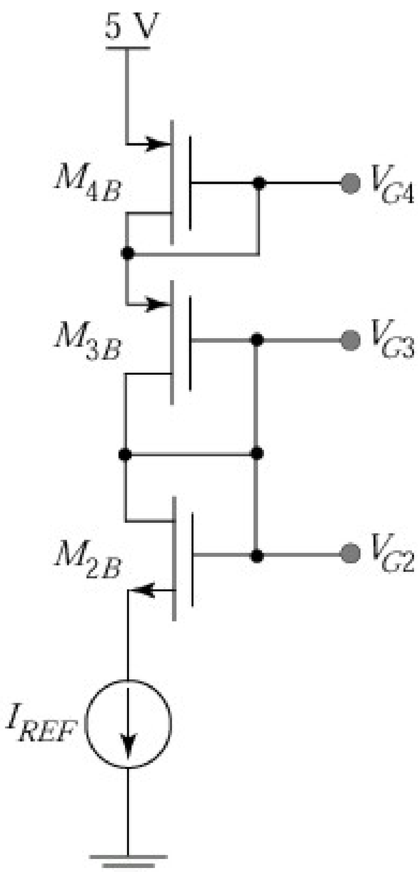
Current Supply Design



Output resistance goal requires large r_{oc} → use cascode current source

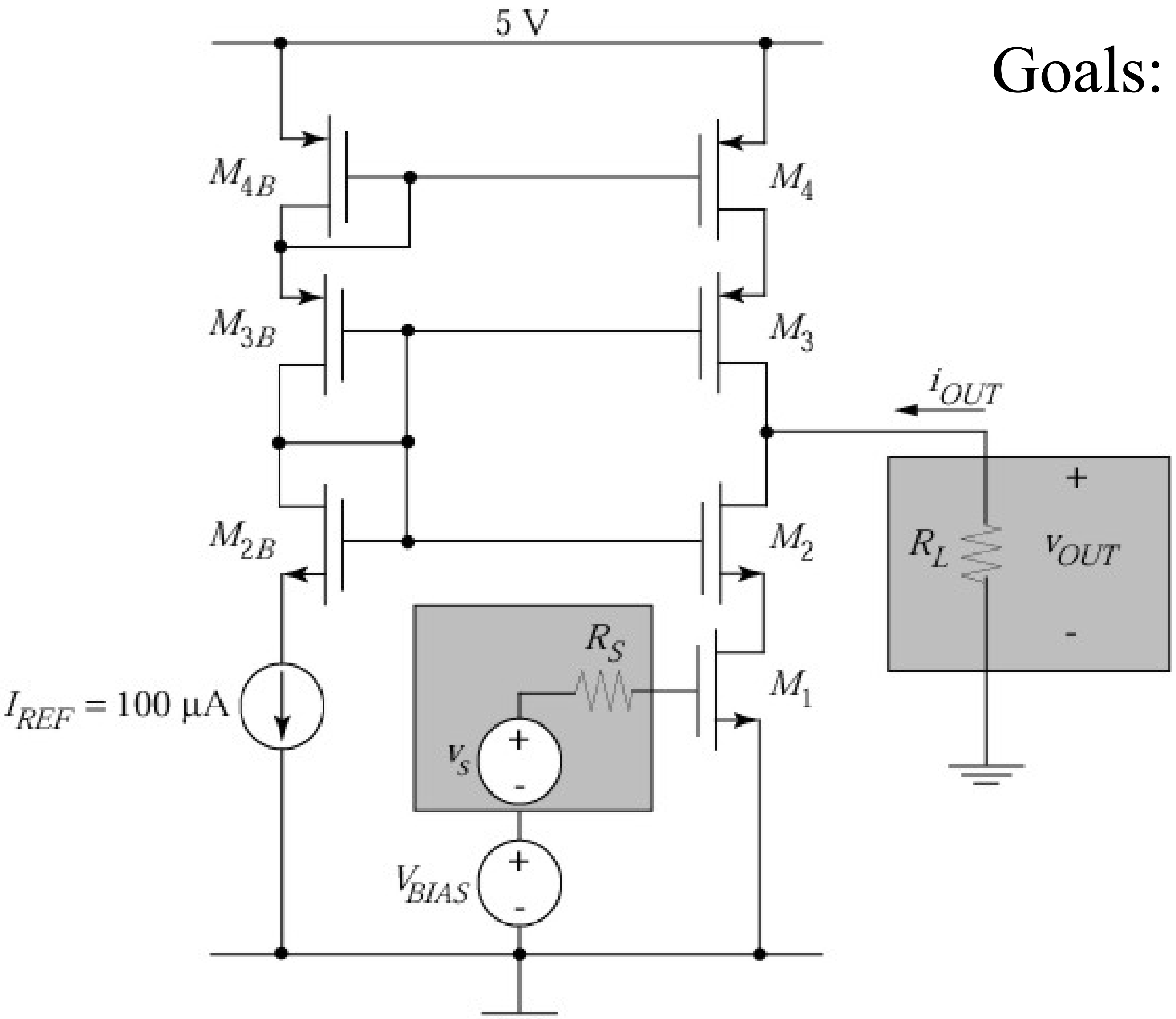
Totem Pole Voltage Supply

DC voltages must be set for the cascode current supply transistors M_3 and M_4, as well as the gate of M_2.



Why include M_{2B}?

Complete Amplifier Schematic



Goals: $g_{m1} = 1$ mS,
$R_{out} = 10\ M\Omega$

Device Sizes

M_1: select $(W/L)_1 = 200/2$ to meet specified $g_{m1} = 1$ mS

→ find $V_{BIAS} = 1.2$ V

Cascode current supply devices: select $V_{SG} = 1.5$ V

$(W/L)_4 = (W/L)_{4B} = (W/L)_3 = (W/L)_{3B} = 64/2$

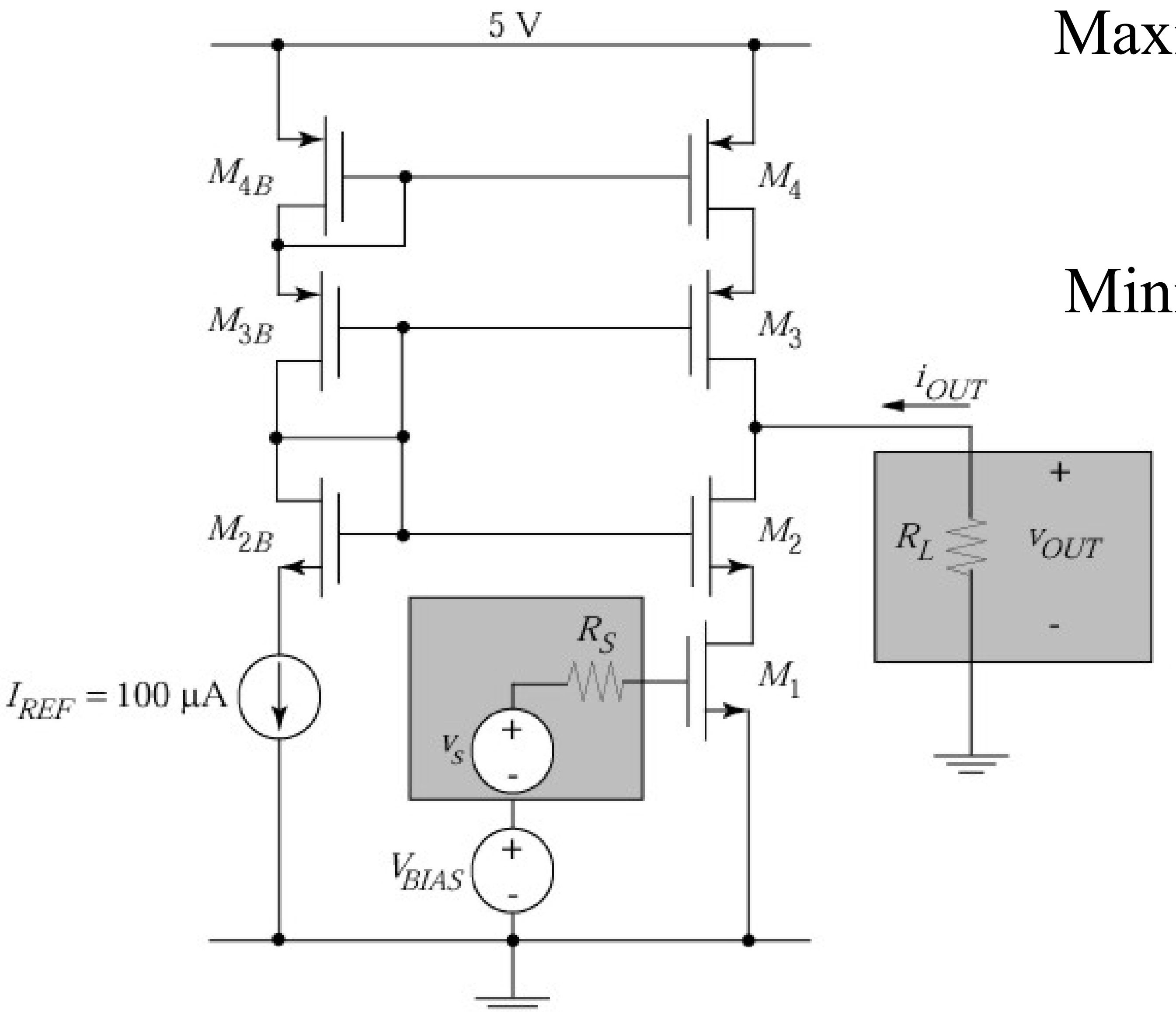
M_2: select $(W/L)_2 = 50/2$ to meet specified $R_{out} = 10$ MΩ

→ find $V_{GS2} = 1.4$ V

Match M_2 with diode-connected device M_{2B}.

Assuming perfect matching and zero input voltage, what is V_{OUT}?

Output (Voltage) Swing



Maximum V_{OUT}

Minimum V_{OUT}

Two-Port Model

Find output resistance R_{out}

λ_n = (1/20) V^{-1}, λ_n = (1/50) V^{-1} at L = 2 μm →
r_{on} = (100 μA / 20 V^{-1})$^{-1}$ = 200 kΩ, r_{op} = 500 kΩ

$$g_{m2} = \frac{2I_{D2}}{V_{GS2} - V_{Tn}} = \frac{2(100\mu A)}{1.4V - 1V} = 500\mu S$$

$$g_{m3} = \frac{2(-I_{D3})}{V_{SG3} + V_{Tp}} = \frac{2(100\mu A)}{1.5V - 1V} = 400\mu S$$

$$R_{out} = r_{oc} \parallel r_{o2}\left(1 + g_{m2}R_{S2}\right) = r_{o3}\left(1 + g_{m3}R_{S3}\right) \parallel r_{o2}\left(1 + g_{m2}r_{o1}\right)$$

Voltage Transfer Curve

Open-circuit voltage gain: $A_v = v_{out} / v_{in} = - g_{m1} R_{out}$