Lecture 37

- Last time:
  – Complete "lecture design" of two-stage CMOS transconductance amplifier
- Today :
  – CMOS cascode transconductance amplifier design example

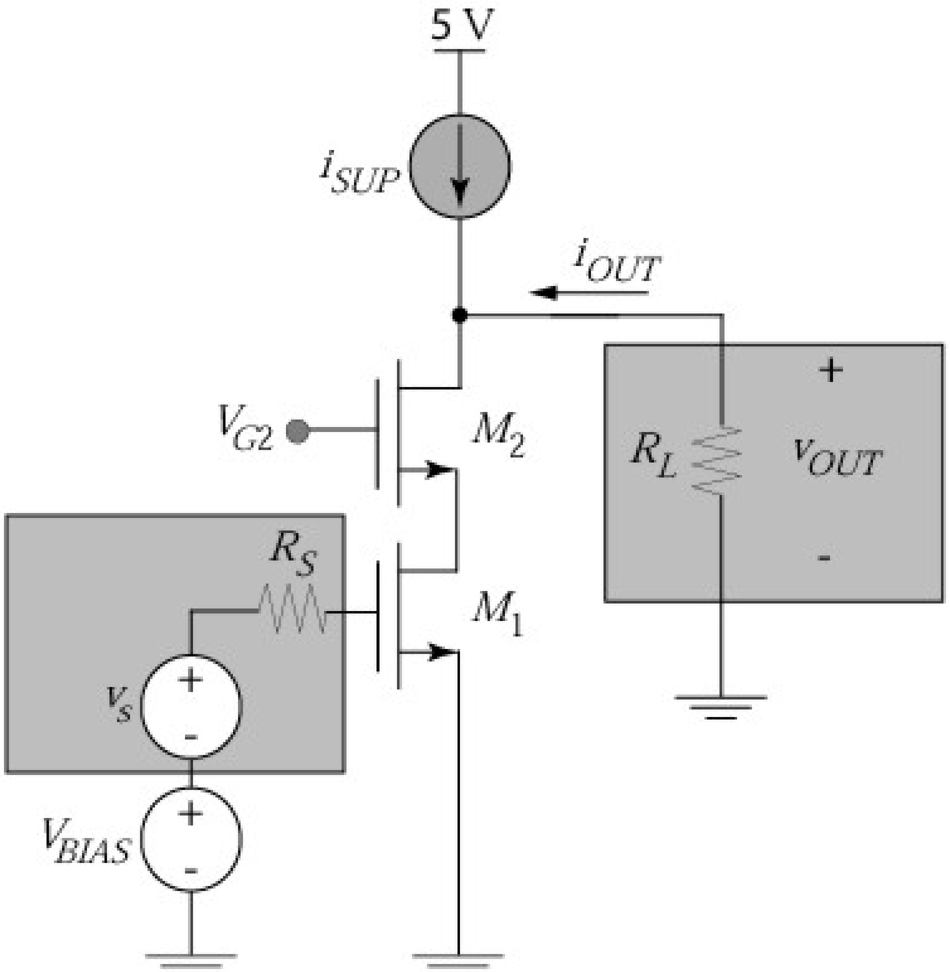
Amplifier Topology

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

Common source – common gate cascode makes sense

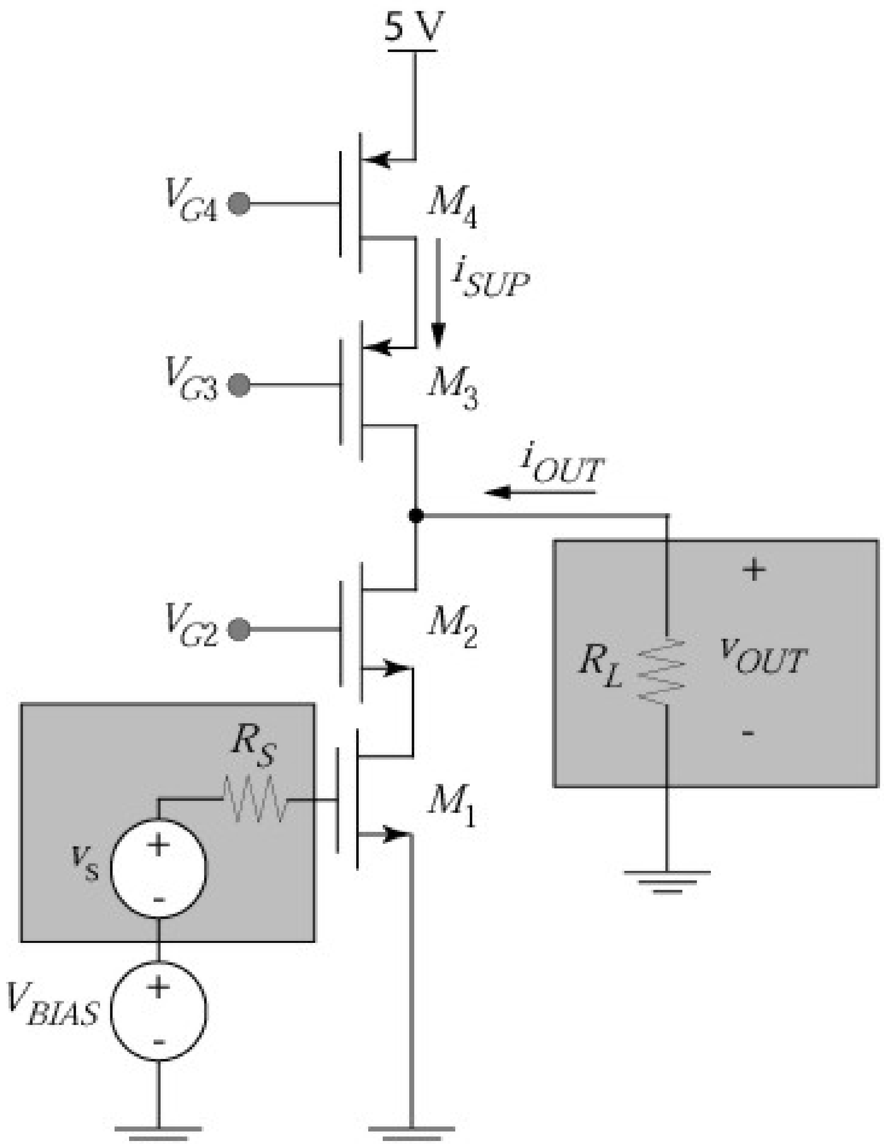
Share the current supply

Amplifier Schematic



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

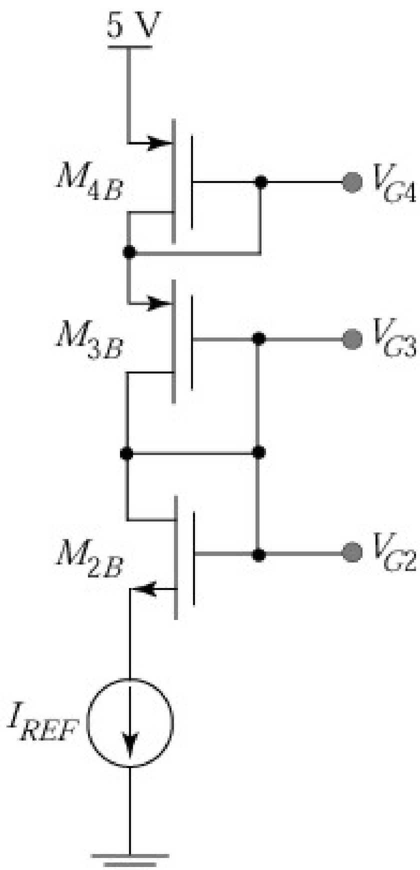
Current Supply Design



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

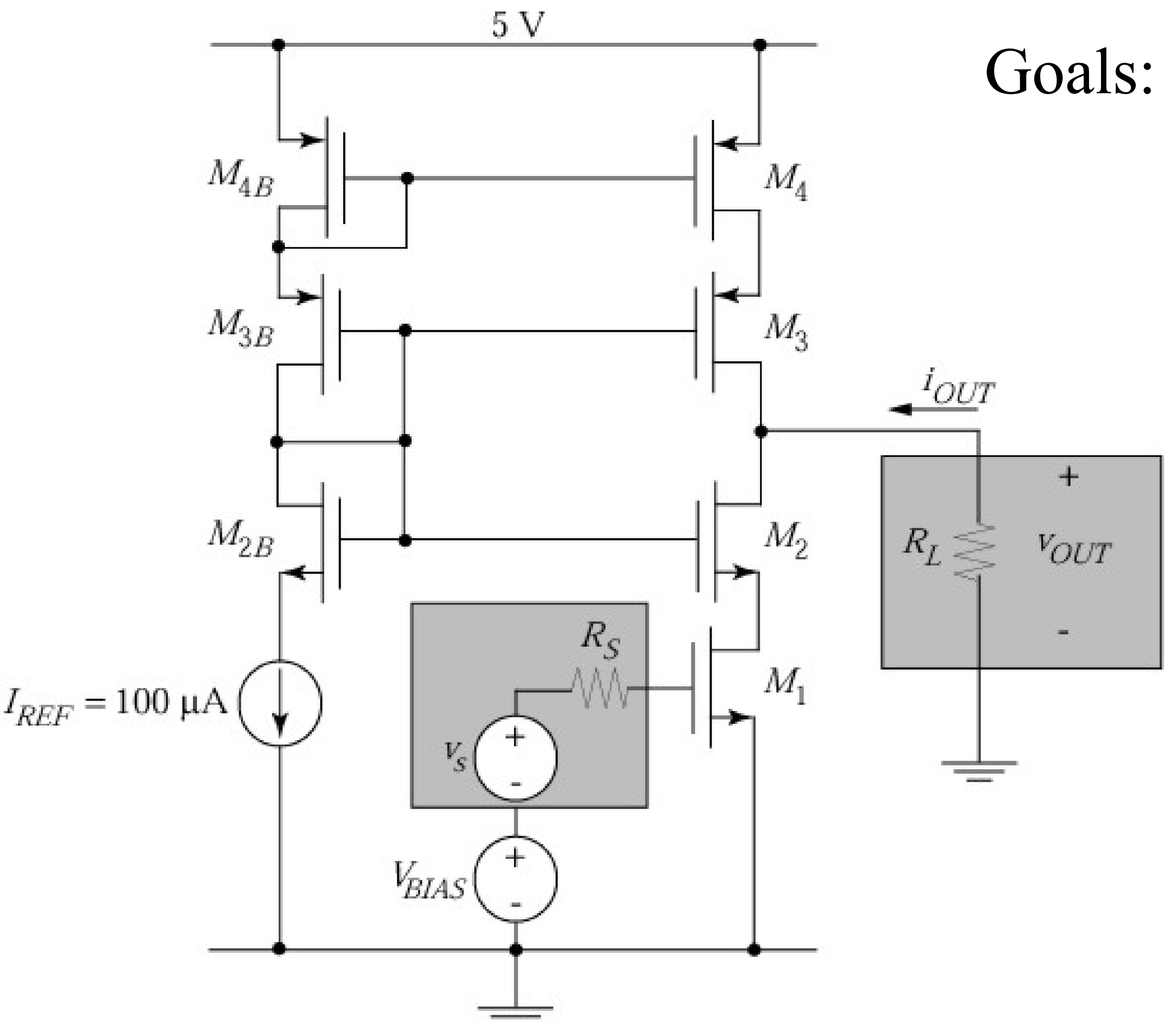
Totem Pole Voltage Supply

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

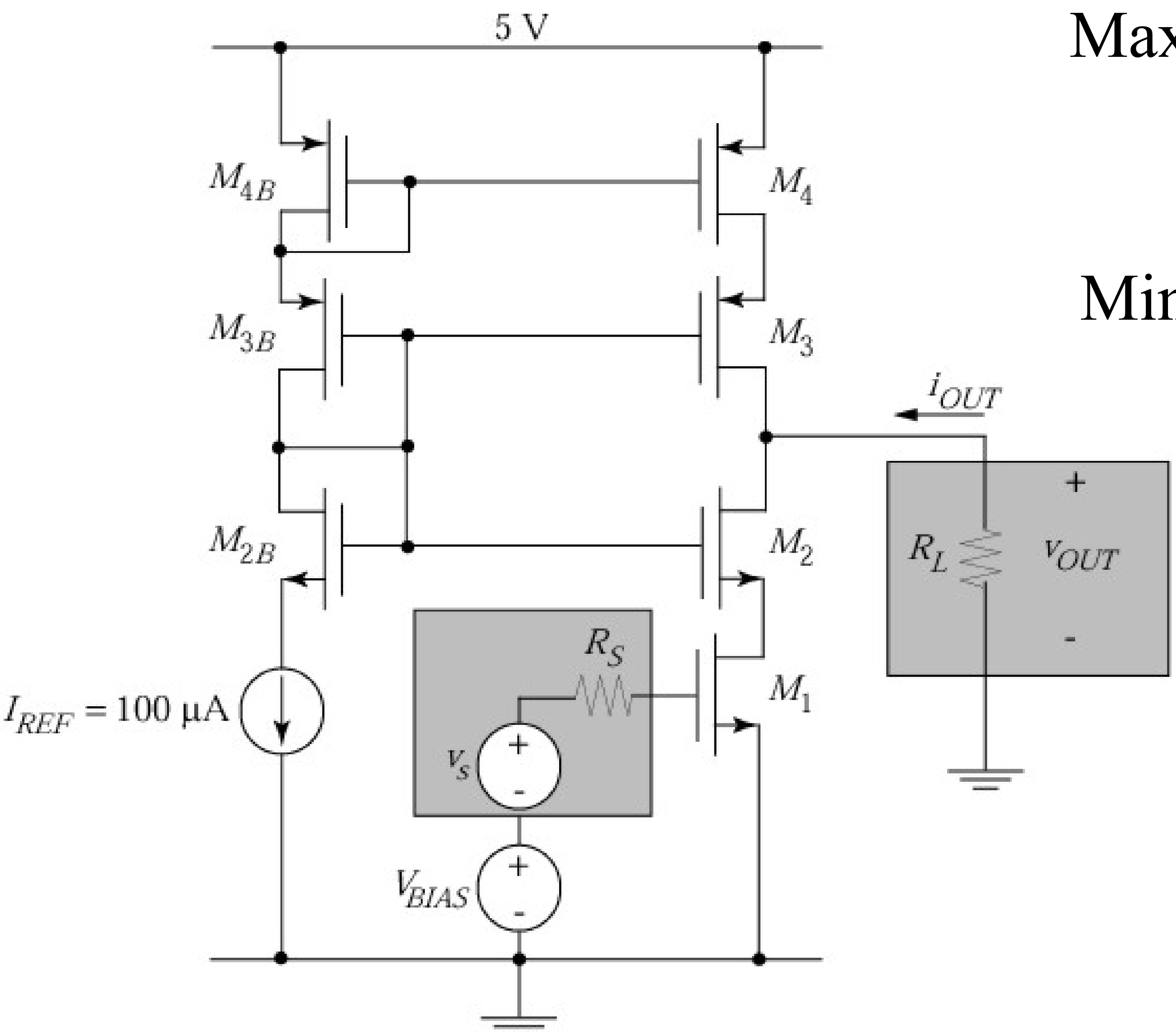
$(W/L)_4 = (W/L)_{4B} = (W/L)_3 = (W/L)_{3B}$ = 64/2

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}

$\lambda_n = (1/20)\ \text{V}^{-1}$, $\lambda_n = (1/50)\ \text{V}^{-1}$ at $L = 2\ \mu\text{m}$ →
$r_{on} = (100\ \mu\text{A} / 20\ \text{V}^{-1})^{-1} = 200\ \text{k}\Omega$, $r_{op} = 500\ \text{k}\Omega$

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

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

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

Voltage Transfer Curve

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