

Lecture 38

- Last time:
 - CMOS cascode transconductance amplifier design example (*FINISHING THIS TODAY*)
- Today :
 - BiCMOS voltage amplifier: example of “dissection” technique for a complicated circuit

KILLER EXAMPLE

ANALYSIS vs. DESIGN.
(TOP → BOTTOM) (BOTTOM → TOP)

($V_{out\ max}$, $V_{out\ min}$)

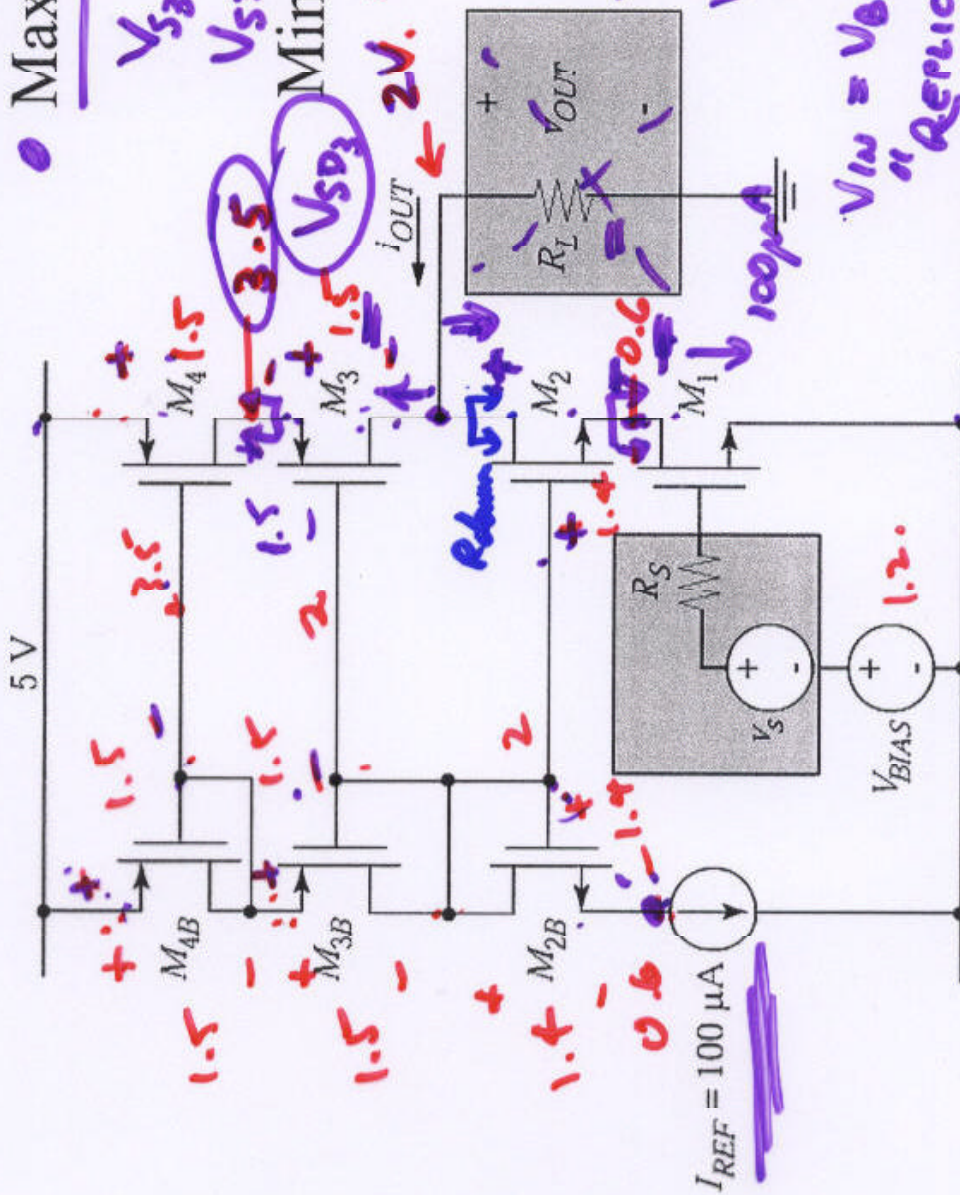
R. T. Howe

Output (Voltage) Swing

Maximum $V_{OUT} = 3.5 - 0.5 = 3V$

$V_{S3} = 3.5V$ (PINNED)

Minimum $V_{OUT} = V_{S6} + V_{TP} = 1.5 + 1.5 = 3V$



$V_{GS2} = 0.6V$

$V_{GS} = V_{TN} + \sqrt{(\cdot)}$

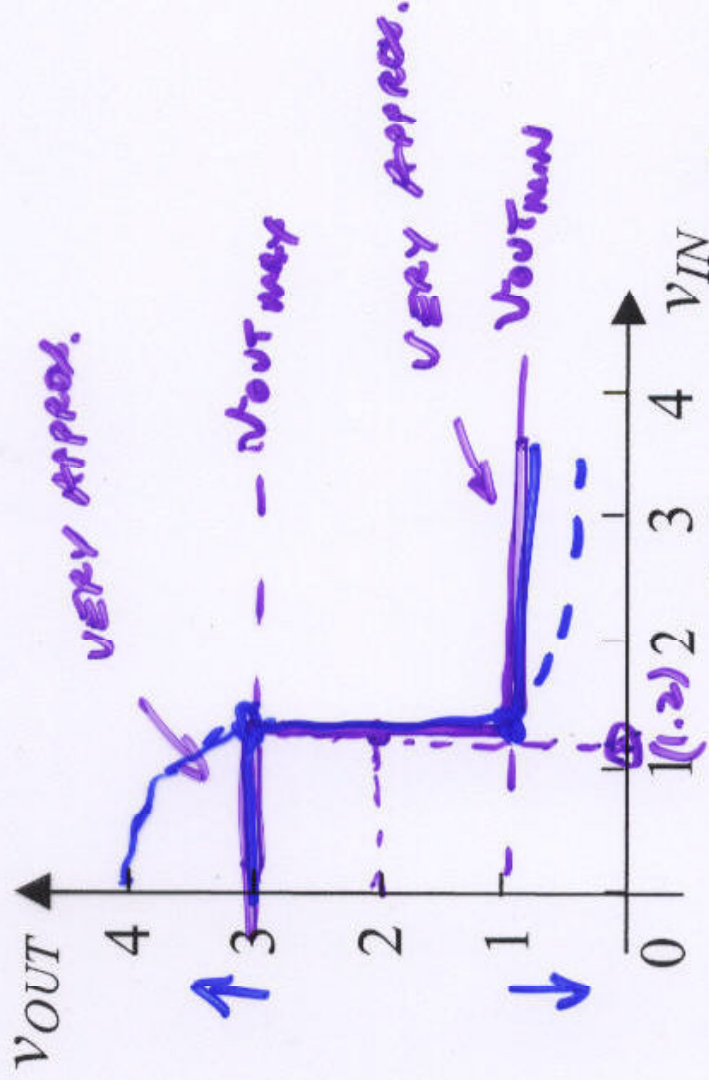
$V_{IN} = V_{BIAS} = 1.2V \dots$
 "REPLICA BIASING"
 $V_{out\ min} = 1V$

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$R_{out} = r_{o2} (1 + g_{m2} \cdot r_{o1})$
 $(W/L)_2 = 50/2$
 $V_{DS2\ sat} = V_{GS2} - V_{TN} = 0.4V$

Voltage Transfer Curve

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



Check
 THIS! $\rightarrow A_v \approx -g_{m1} \cdot R_{out} \approx -10^{-3} \times 10^7 = \frac{d v_{out}}{d v_{in}} \approx -10,000$
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 unloaded $R_L \rightarrow \infty$
 $R_{out} \rightarrow \infty$

Two-Port Model

$G_m \uparrow$
 $R_{out} \uparrow$
 $V_{out,max} - V_{out,min} \uparrow$

Find output resistance R_{out}

$$\lambda_n = (1/20) \text{ V}^{-1}, \lambda_p = (1/50) \text{ V}^{-1} \text{ at } L = 2 \mu\text{m} \rightarrow$$

$$r_{on} = (100 \mu\text{A} / 20 \text{ V}^{-1})^{-1} = 200 \text{ k}\Omega, r_{op} = 500 \text{ k}\Omega$$

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

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

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

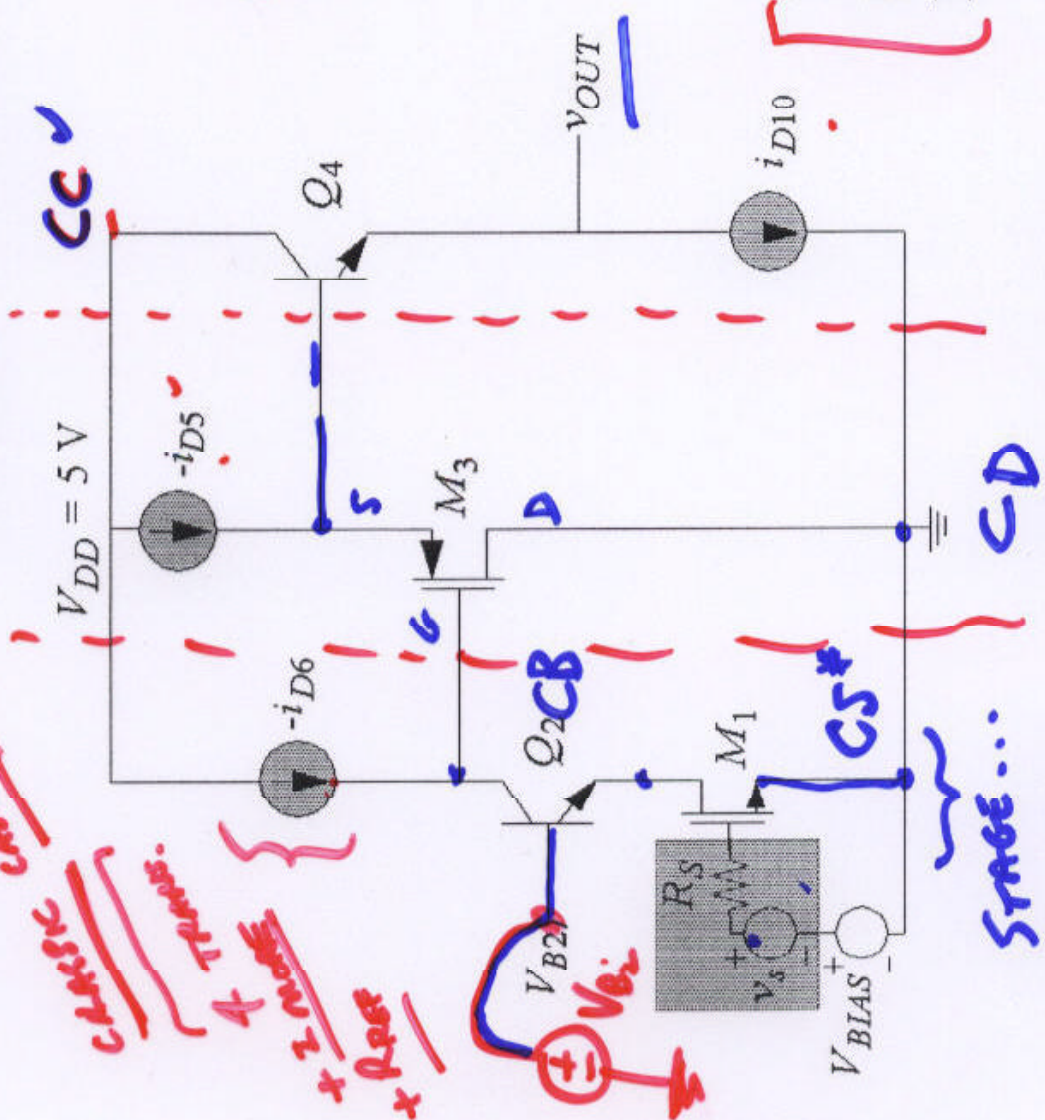
cascode I-supply r_{o1}
 $r_{o1} = 100$
 $g_{m2} r_{o1} = 0.5 \text{ mS} \times 200 \text{ k}\Omega$
 "Return"



$$100 \times 0.2 \mu\text{S} = 20 \mu\text{S}$$

What's Left?

CLASSIC CASCODE
4 TRANS.
2 NODES
R_{REF}

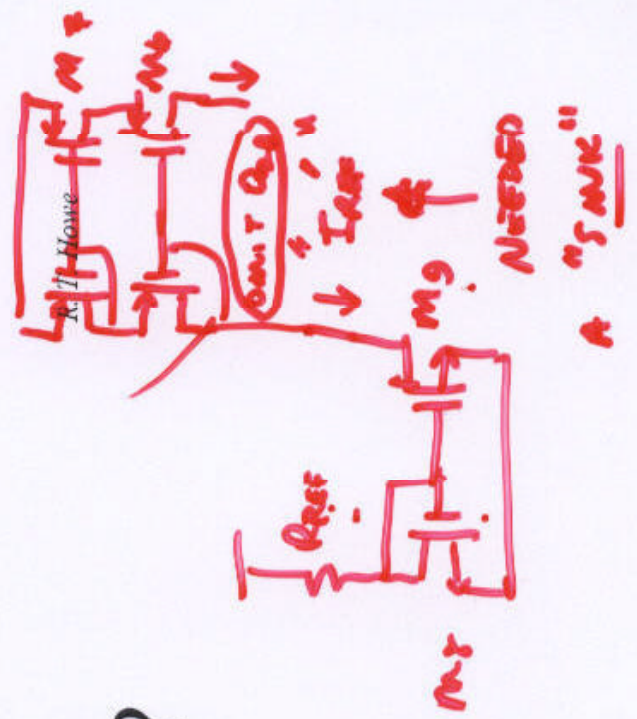


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STAGE...

STAGES.

V-BUFFERS → Root Source!



Voltage at base of Q_2 is set by totem pole

Cutting Through the Complexity

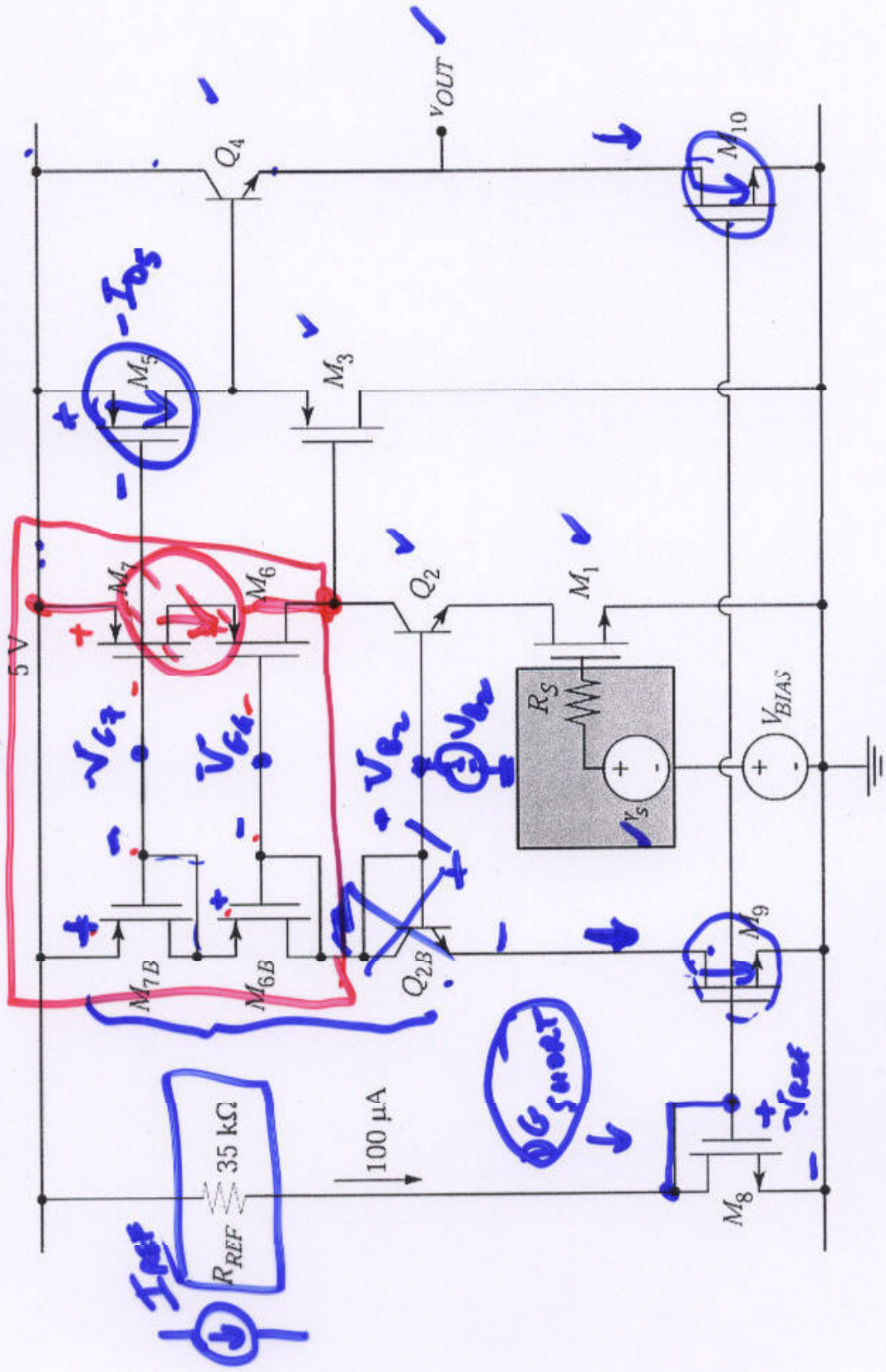
Two Approaches:

(Howe) 1. Eliminate “background” transistors to reduce clutter

(Sodini) 2. Identify the “signal path” between the input and output

v_s + other small-signals generated by v_s .

Multi-Stage Voltage Amplifier



CURRENT / VOLTAGE SUPPLIES