Lecture 35: Differential Pair

- Announcements:
- HW#10 online and due Friday Nov. 16
- Lab 6 online and due 5 p.m., Friday, Dec. 7
  - Last Friday's lecture said a lot about how to do Lab#6
- Lecture 33 video now online at CalCentral
  - I will also place it on our website at some point
- Graded midterms coming back today
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- Lecture Topics:
  - Differential Pair
  - Cascode Topology – or maybe leave for discussion section
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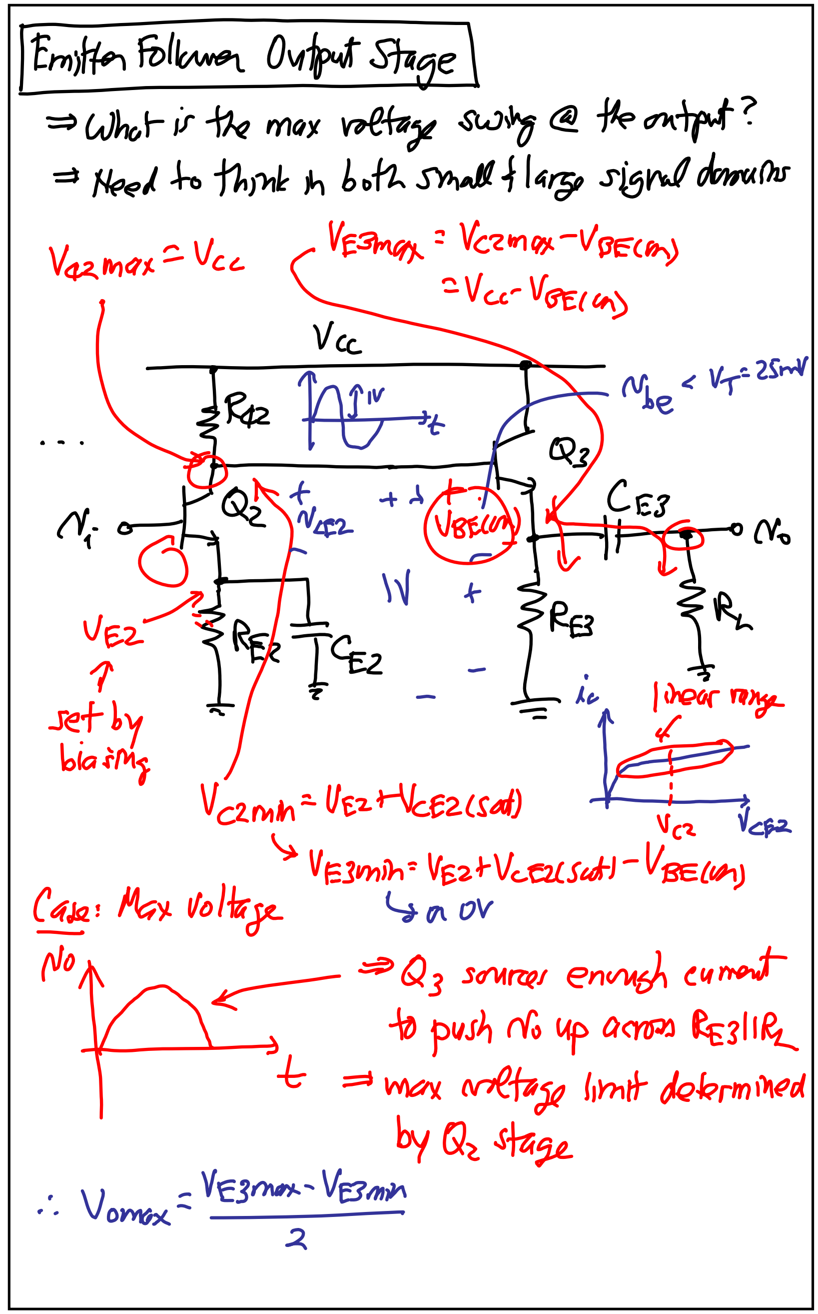
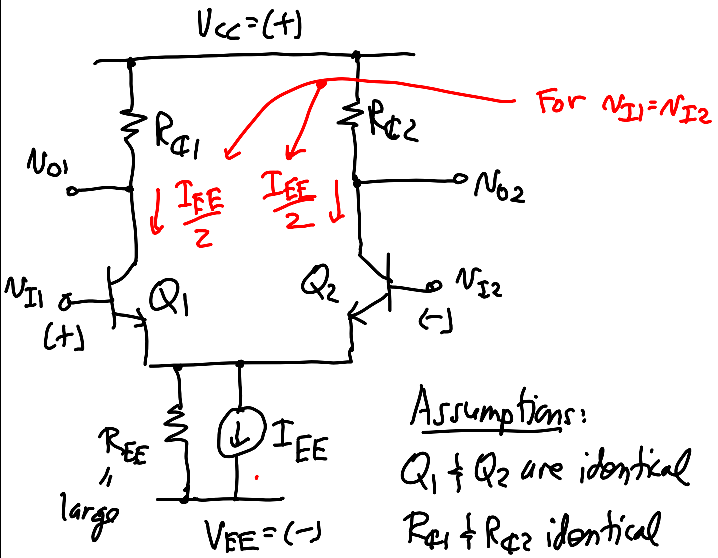
- Last Time:
- Covered purposeful design and output stages, then started differential pairs
- Now continue this …
- … but first, one more thing about output stages: the stage before the output stage



Differential Pair → A Simple Op Amp



Assumptions:

Q_1 & Q_2 are identical

R_{C1} & R_{C2} identical

Purpose: Amplify the difference between two signals regardless of their common-mode values.

Definitions.

$v_{ID}=v_{I1}-v_{I2}$ (differential input)

$v_{ICM}=\frac{v_{I1}+v_{I2}}{2}$ (common-mode input)

$v_{I1}=v_{ICM}+\frac{v_{ID}}{2}$

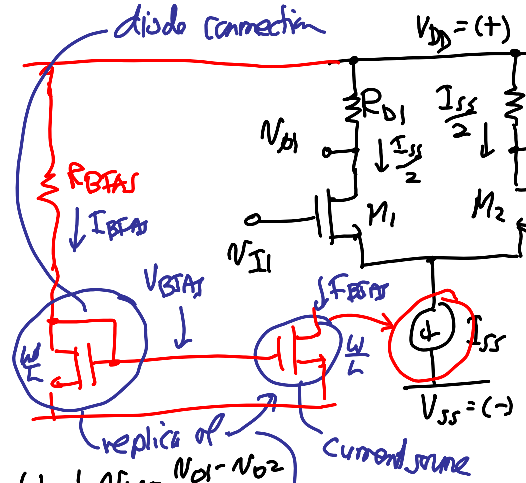
$v_{I2}=v_{ICM}-\frac{v_{ID}}{2}$

Differential Gain $= A_d = \frac{v_{o1}-v_{o2}}{v_{id}} = \frac{v_{od}}{v_{id}}$ (want BIG)

Common-Mode Gain $= A_{cm} = \frac{v_{o1}}{v_{icm}} = \frac{v_{o2}}{v_{icm}}$ (want SMALL)

Common-Mode Rejection Ratio $= CMRR = \frac{A_{dm}}{A_{cm}}$

(want BIG)

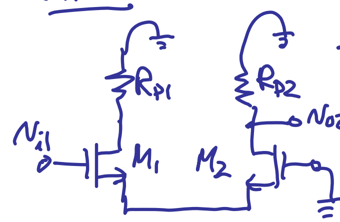


M_1 & M_2 identical

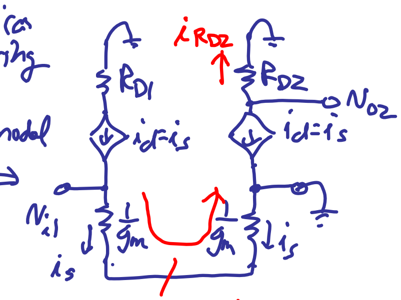
R_{D1} & R_{D2} identical

Want $v_{id}=\frac{v_{o1}-v_{o2}}{v_{i1}-v_{i2}}$

S.S. ckt.



T-model ⇒



$i_{RD2}=\frac{v_{i1}}{\frac{2}{g_m}}=\frac{1}{2}g_m v_{i1}$

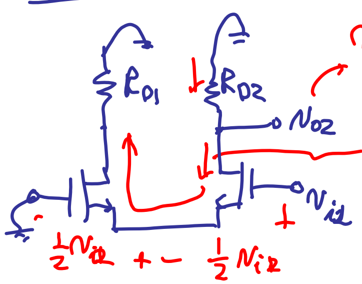
$v_{o2} = i_{R_{D2}} R_{D2} \doteq +\frac{1}{2} g_m v_{i1} R_{D2}$

$\therefore \frac{v_{o2}}{v_{i1}} = \frac{1}{2} g_m R_D$ $\quad [R_D = R_{D1} = R_{D2}]$

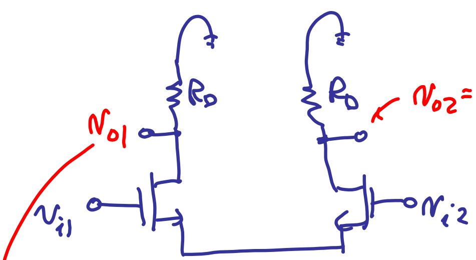
$[g_m = g_{m1} = g_{m2}]$

Get $\frac{v_{o2}}{v_{i2}}$:

$v_{o2} = -\frac{1}{2} g_m R_{D2} v_{i2}$



$i_{d2} = g_{m2}\left(\frac{1}{2} v_{i2}\right) = \frac{1}{2} g_m v_{i2}$



$v_{o2} = \frac{1}{2} g_m R_D v_{i1} - \frac{1}{2} g_m R_D v_{i2}$

w/ similar analysis → $v_{o1} = -\frac{1}{2} g_m R_D v_{i1} + \frac{1}{2} g_m R_D v_{i2}$

$v_{o1} = -\frac{1}{2} g_m R_D (v_{i1} - v_{i2})$

$v_{o2} = +\frac{1}{2} g_m R_D (v_{i1} - v_{i2})$

$v_{od} = v_{o1} - v_{o2} = -g_m R_D (v_{i1} - v_{i2})$

$$\frac{v_{od}}{v_{id}} = A_{dm} = -g_m R_D$$

- Hand back midterms and skim through solutions

Midterm 2 Statistics	
Top Score	90
Average	56
Std. Dev.	16
Median	57