R. T. Howe

Thévenin

$\boxed{\text{BANDWIDTH}}$

Lecture 41

$R_{Ti} C_i \rightarrow \underline{\underline{\omega_1}} \approx \frac{1}{\sum R_{Ti} C_i}$

- Last time:
  - Applications of open-circuit time constant analysis: CE amplifier and cascode amplifier
- Today :
  - The four-stage voltage amplifier: using OCTC to find the dominant pole
  - Introduction to differential amplifiers

Gain-Bandwidth Product

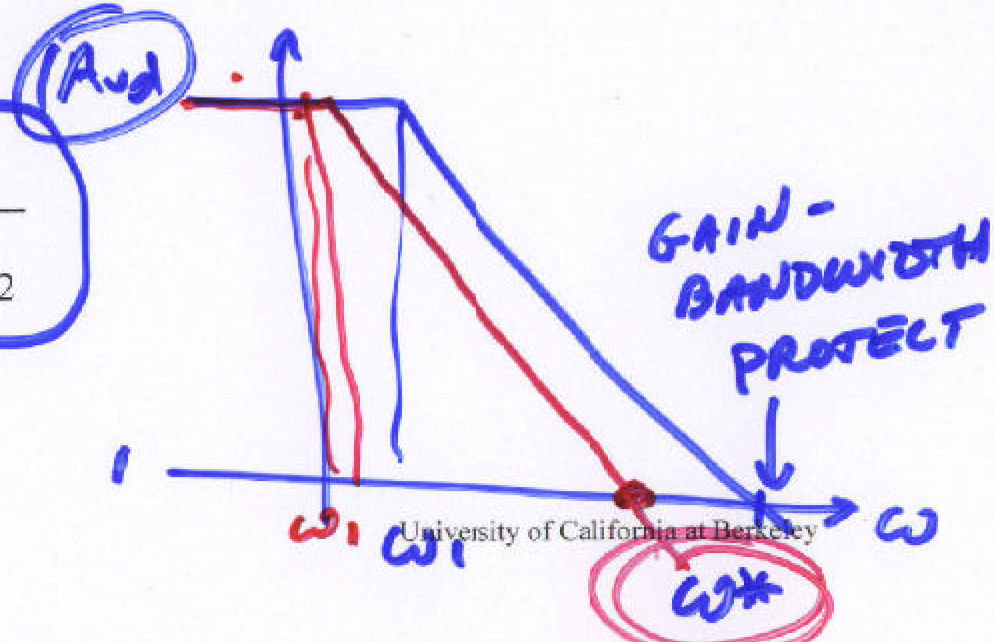
Metric for amplifier performance: note that

$$\left|A_v\left(j\omega^*\right)\right| = 1 \quad \text{when } \omega^* = \left|A_{vo}\right|\omega_1$$

$$\left|A_{vo}\right|\omega_1 = \frac{g_{m1}R_L}{R_S C_{gs1} + R_S\left(1 + g_{m1}/g_{m2}\right)C_{gd1} + C_{\pi 2}/g_{m2} + R_L C_{\mu 2}}$$

Special case: small R_S

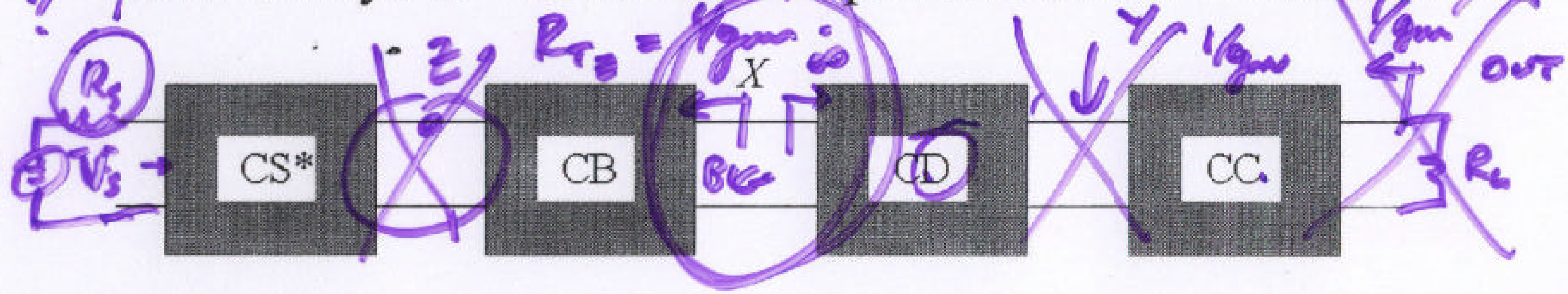
$$\boxed{\left|A_{vo}\right|\omega_1 \approx \frac{g_{m1}R_L}{C_{\pi 2}/g_{m2} + R_L C_{\mu 2}}} \approx \omega_T .$$



Rs small

Qualitative Insight

Could always do "brute force" open-circuit time constants



- CS*-CB is a wideband stage … so is the CD-CC buffer

→ Look for large $R_{Tx}C_x$ products: high-impedance nodes are likely candidates

$R_{out_{CB}} \parallel R_{in_{CD}} \rightarrow$ BIG …

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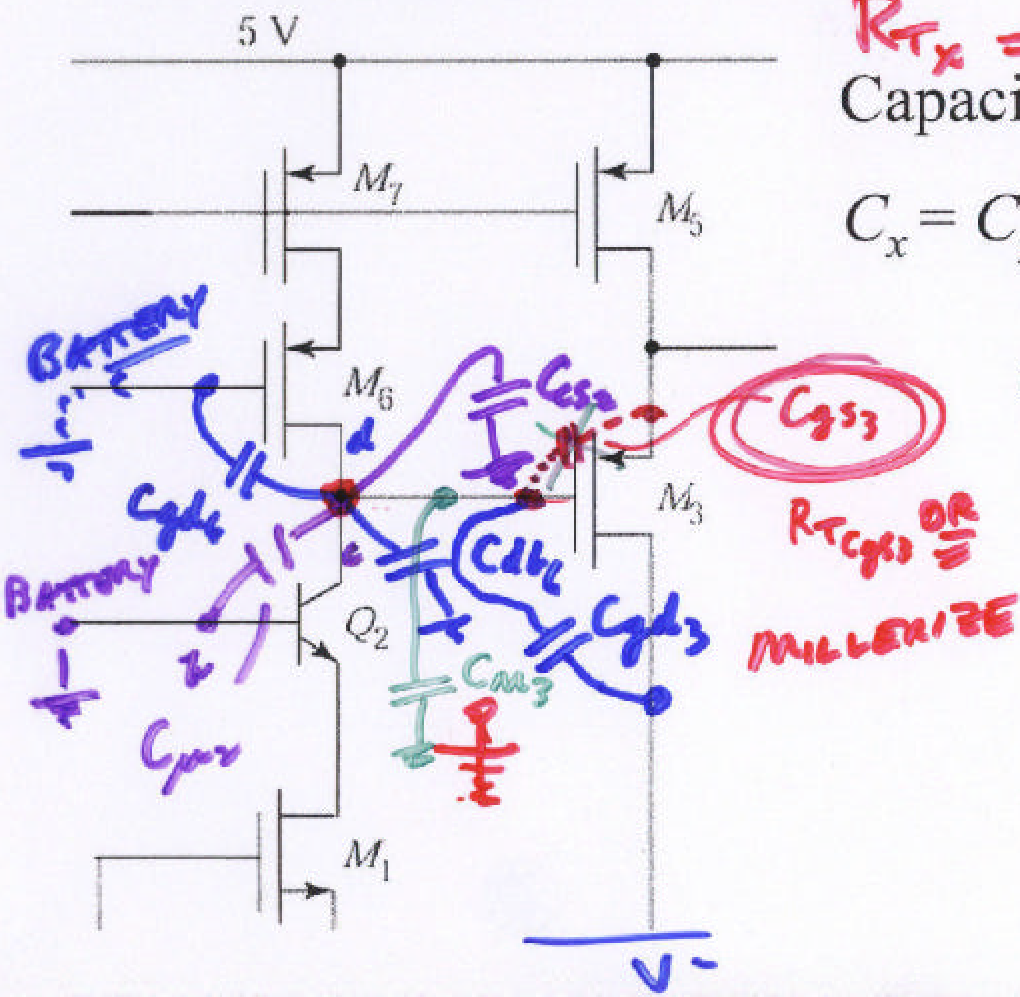
Node X

CS*-CB is a wideband stage … so is the CD-CC buffer

resistance.

"High ~~impedance~~ node" is node X … look at $R_{Tx}C_x$

R_{Tx} =



Capacitance:

$$C_x = C_{gd6} + C_{db6} + C_{\mu 2} +$$

$$C_{cs2} + C_{gd3} + C_{M3}$$

Miller for CD stage (M_3)

$R_{T C_{gs3}}$ OR MILLERIZE

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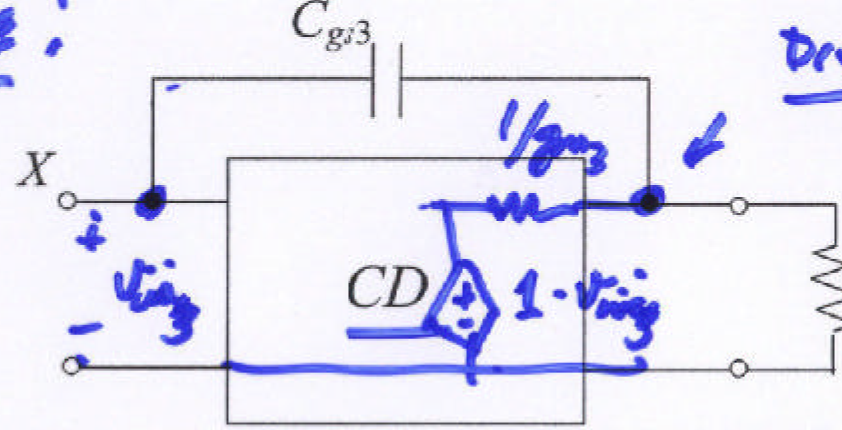
Finding the Miller Capacitance C_{M3} SMALL!

3rd STAGE!



LOAD FOR STAGE 3.

Gain across C_{gs3}: $A_{vC_{gs3}} = \dfrac{R_{L\,eff}}{1/g_{m3} + R_{L\,eff}} \approx 1$

BIG

$R_{L\,eff} = R_{in\,CC} = r_{\pi 4} + \beta_o (R_E \| \ldots)$

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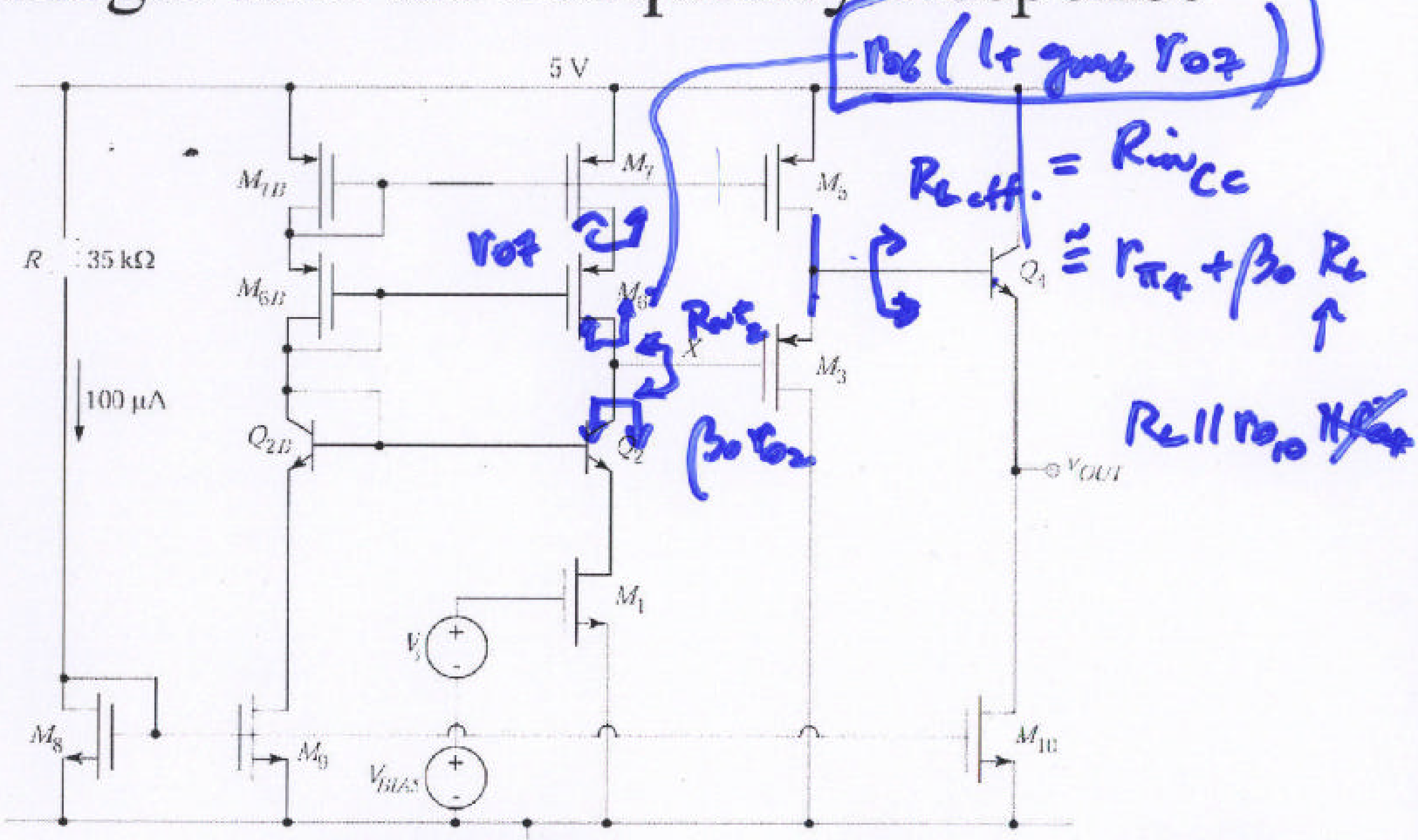
Insight into the Frequency Response



R_T; C_i

$1/g_m$ ... IGNORE

$\beta_o r_o$ ... LOOK AT IT!

• $C_x = \sum$ BUNCH OF STUFF

Dominant Pole of Voltage Amplifier

Thévenin resistance for C_X:

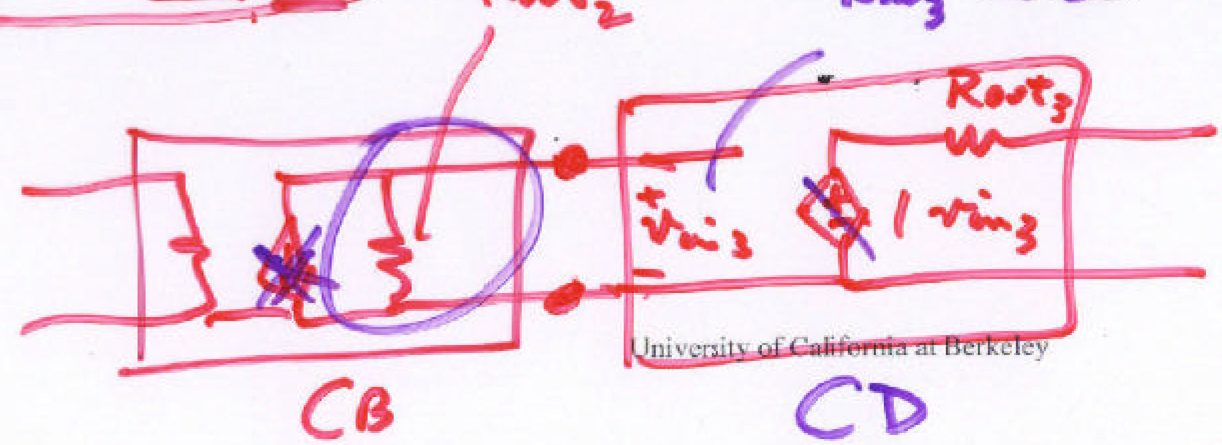
$$R_{Tx} = R_{out2} \,\|\, R_{in3} = R_{out,CB} \,\|\, R_{in,CD}$$

$$R_{Tx} = r_{oc} \,\|\, r_{o2}(1 + g_{m2}\underbrace{(r_{\pi 2} \,\|\, R_{S2})}_{\approx r_{\pi 2}}) \cong r_{o6}(1 + g_{m6} r_{o7}) \,\|\, r_{o2}\beta_o$$

HUGE

Dominant pole: $\boxed{\omega_1^{-1} \approx R_{Tx} C_x}$

Rin3 → ∞



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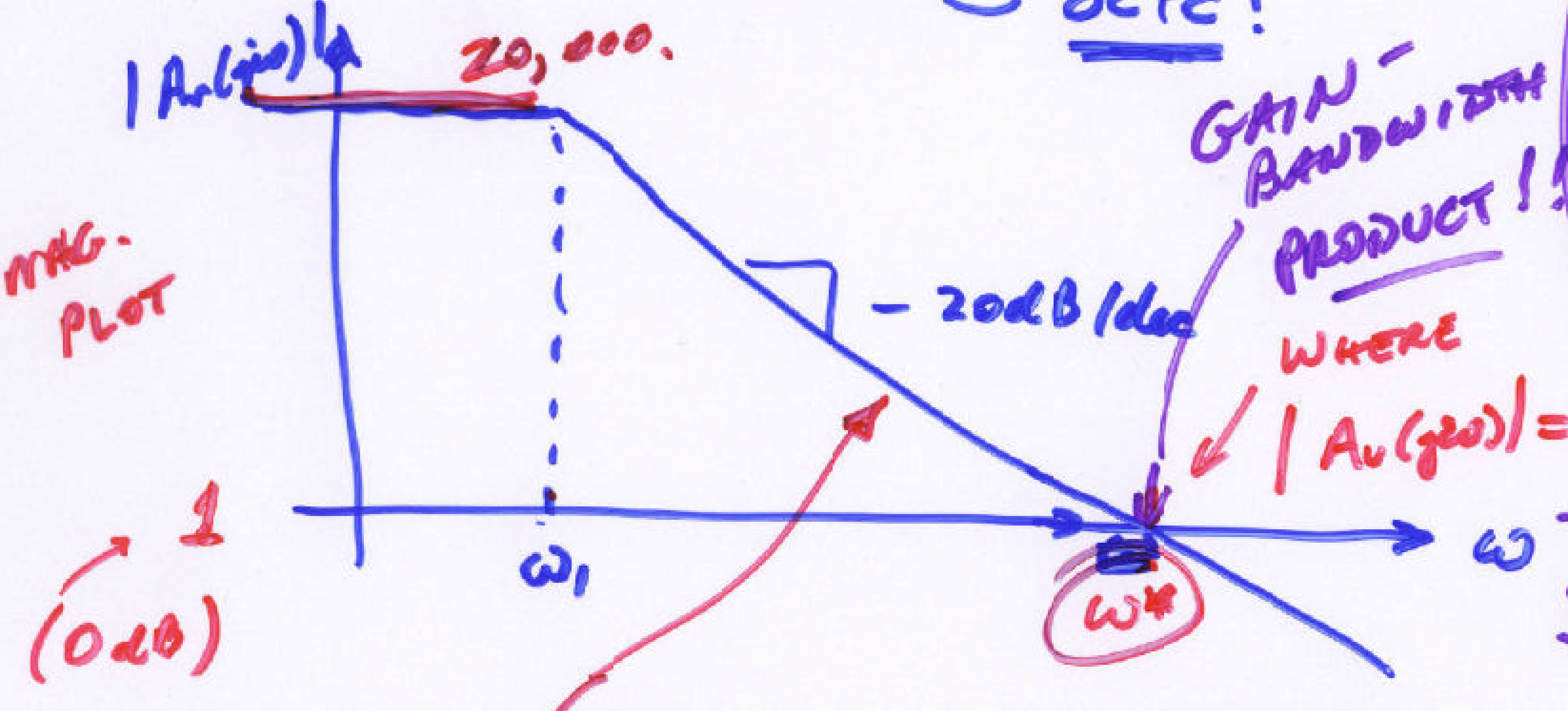
• **OCTC** → LOW-PASS FILTER!

$$A_v(j\omega) \cancel{=} \frac{|A_{vo}|}{1 + j\omega/\omega_1} \leftarrow \text{CHAP. 9!}$$

$\approx$ ← **OCTC**!

$\hat{\omega}$ SMALL-ISH



$$\omega^* \cong |A_{vo}|\,\omega_1$$

$$\frac{|A_{vo}|}{\omega^*/\omega_1}$$

$$1 = \frac{|A_{vo}|}{|1 + j\omega^*/\omega_1|} = \frac{|A_{vo}|}{\sqrt{\cancel{1} + (\omega^*/\omega_1)^2}} \approx$$

Magnitude Bode Plot

Low-frequency voltage gain was found in Lecture 38:

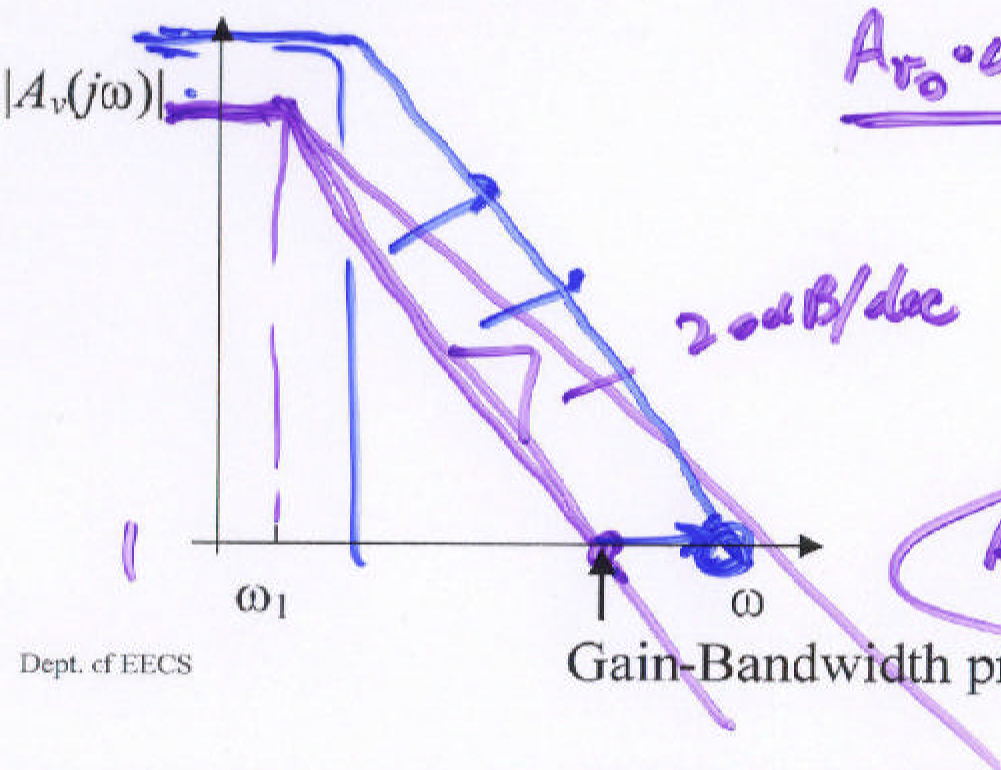
$$A_v = -g_{m1}\boxed{\left(\beta_o r_{o2} \,\|\, r_{o6}\left(1+g_{m6}r_{o7}\right)\right)}$$ ← SAME RESISTOR

(neglect loading at output ($R_L >> R_{out}$)) R_{Tx} !!

$\underline{A_{v_0} \cdot \omega_1} \cong \frac{\cancel{(-g_{m1}[R_{out,CB}])}}{\cancel{(R_{out,CB})} \cdot C_x}$

$R_{Tx} C_x = \omega_1^{-1}$

$A_{v_0} \omega_1 \approx g_{m1}/C_x$



Gain-Bandwidth product = unity gain frequency

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Differential Amplifiers

What's wrong with our "EE 105" amplifiers? 140!

1.2035 V.

1. Customer must supply V_{BIAS} or I_{BIAS} – impractical!

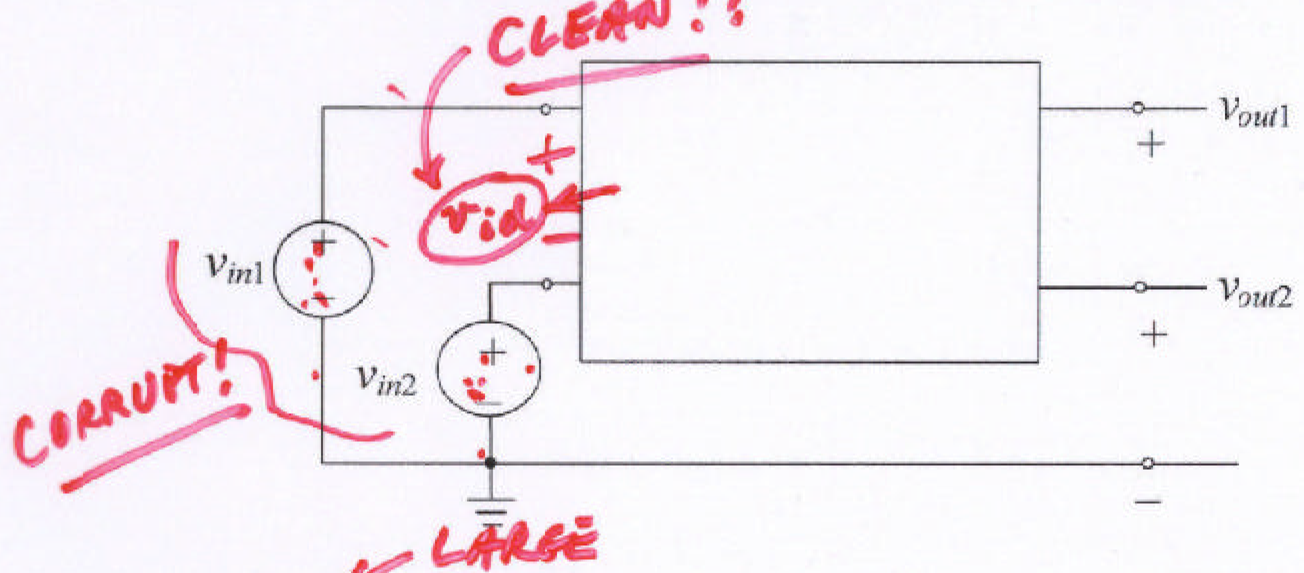
2. The input signals and output signals are referenced to ground or "single-ended" → + v_{in} −

   they're easily corrupted by a variety of interfering signals (e.g., loops in your circuit picking up radio stations or cell phones, V_{DD} has high-frequency components from lightning strikes in the Sierra, etc.)

CHAP. 11.

The Differential Amplifier Concept

The basic idea: amplify the *difference* between two inputs and reject the common component



$$v_{out,diff} = A_{v,diff}(v_{in,diff}) = A_{v,diff}(v_{in1} - v_{in2}) \ldots \text{large}$$

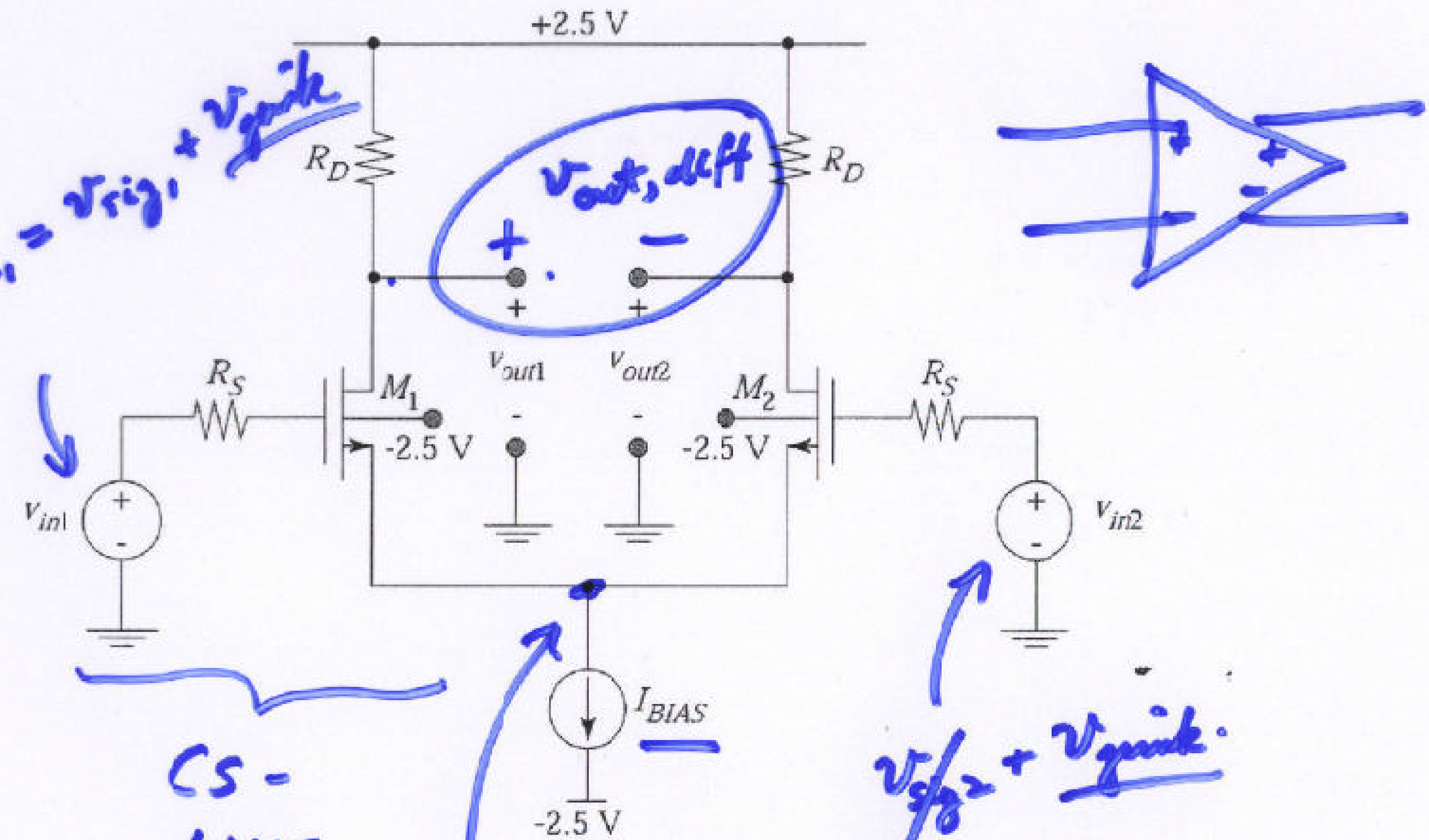
$$v_{out,\,comm} = A_{v,comm}(v_{in,com}) = A_{v,comm}\,[(v_{in1} + v_{in2})/2] \ldots \text{small}$$

SMALL

DUE TO JUNK.

A Simple MOS Differential Amplifier

$v_{in1} = v_{sig1} + v_{guide}$



CS-LIKE

SS GROUND FOR... DIFFERTIAL INPUTS

$v_{sig2} + v_{guide}$

$-v_{sig1}$