

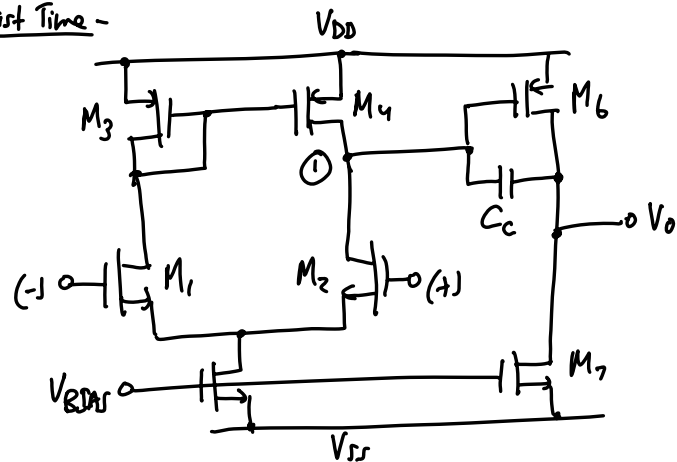
• Announcements:

- ↪ Midterm Exam: Thursday, 3/19, 12:30-2 p.m. (during normal class time)
- ↪ Review Session; Tuesday evening, 7-9 p.m., in 145 McCone

• Today:

- ↪ Compensation (1<sup>st</sup> Pass)
- ↪ Slew Rate (1<sup>st</sup> Pass)
- ↪ Output Stages

Last Time -



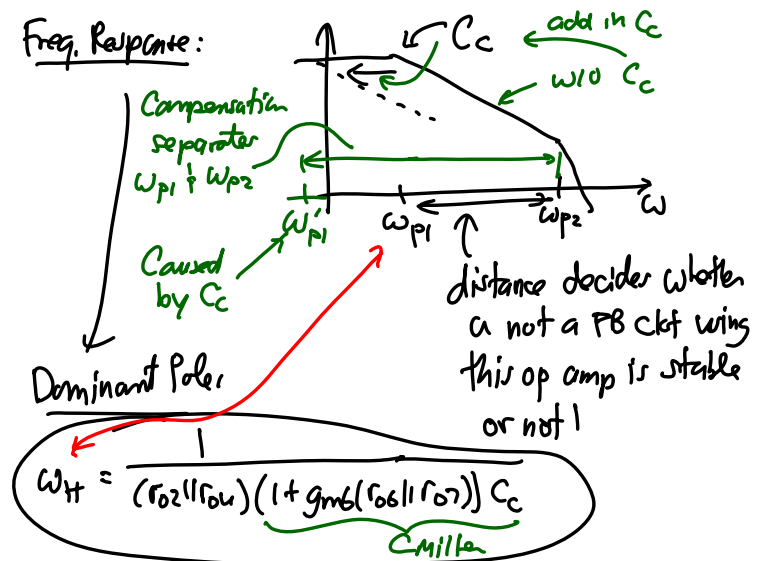
Gain -

$$1^{st} \text{ Stage: } A_{v1} = \frac{V_{O1}}{V_{i1}} = -g_{m2}(r_{o2} || r_{o4})$$

$$2^{nd} \text{ Stage: } A_{v2} = \frac{V_O}{V_{O1}} = -g_{m6}(r_{o6} || r_{o7})$$

$$A_v = A_{v1} A_{v2} = g_{m2}(r_{o2} || r_{o4}) g_{m6}(r_{o6} || r_{o7})$$

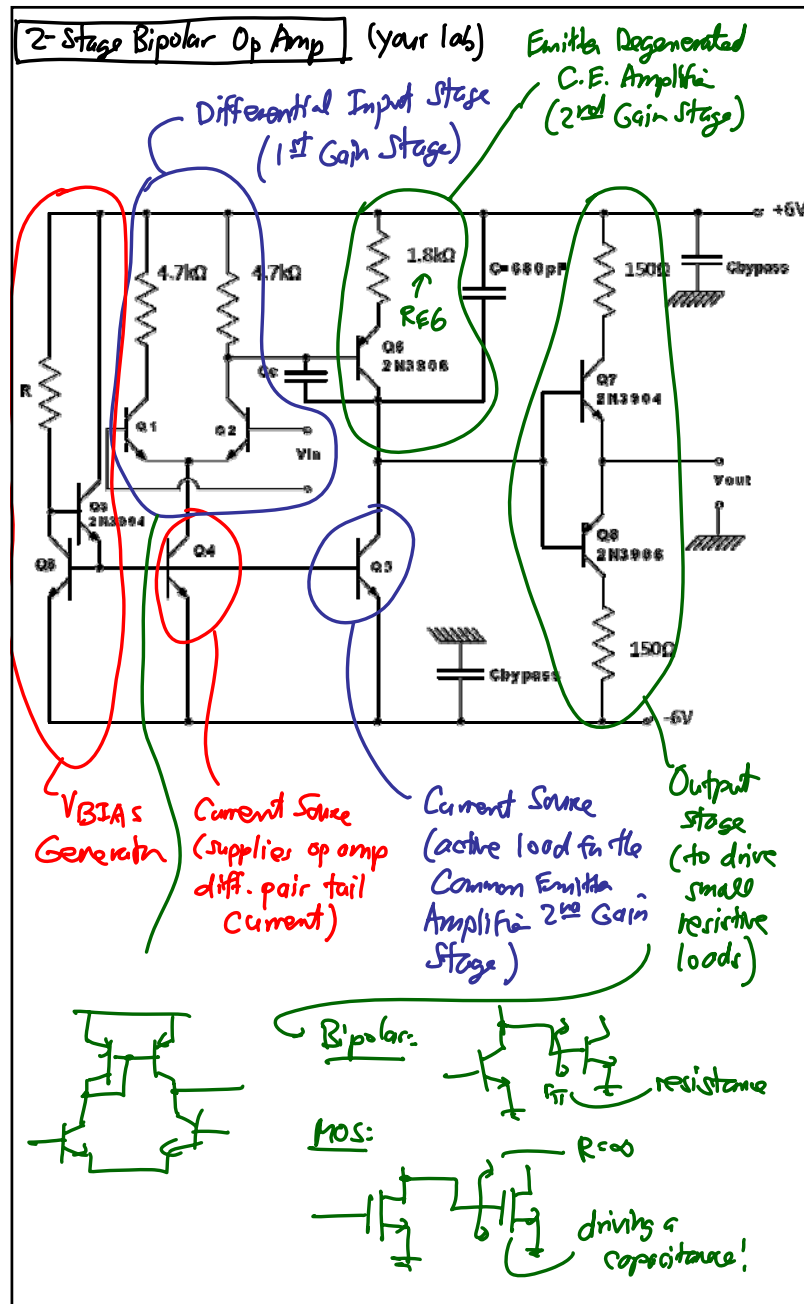
Freq. Response:



Output Swing:

$$V_{swing} = V_{DD} - V_{DS} - |V_{OV6}| - V_{OV7}$$

over  $\rightarrow$

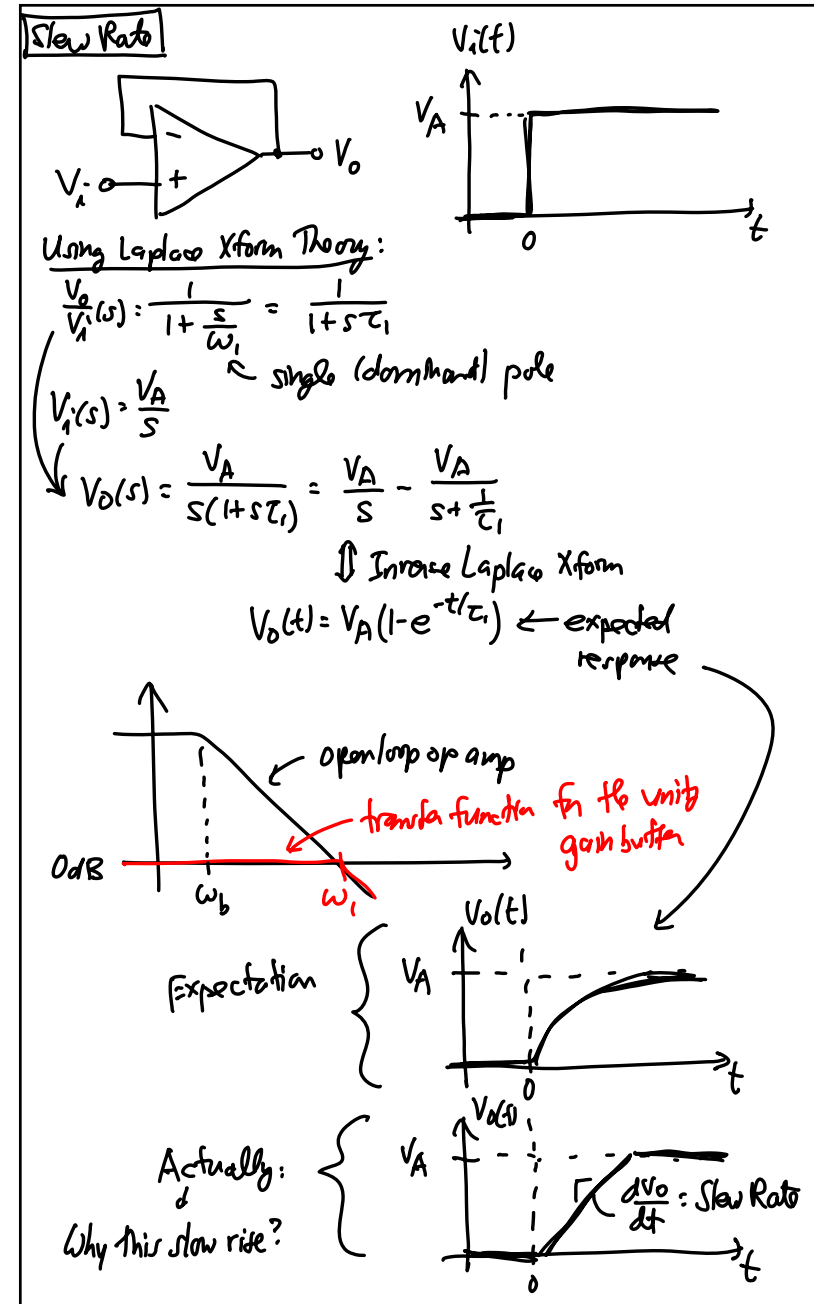
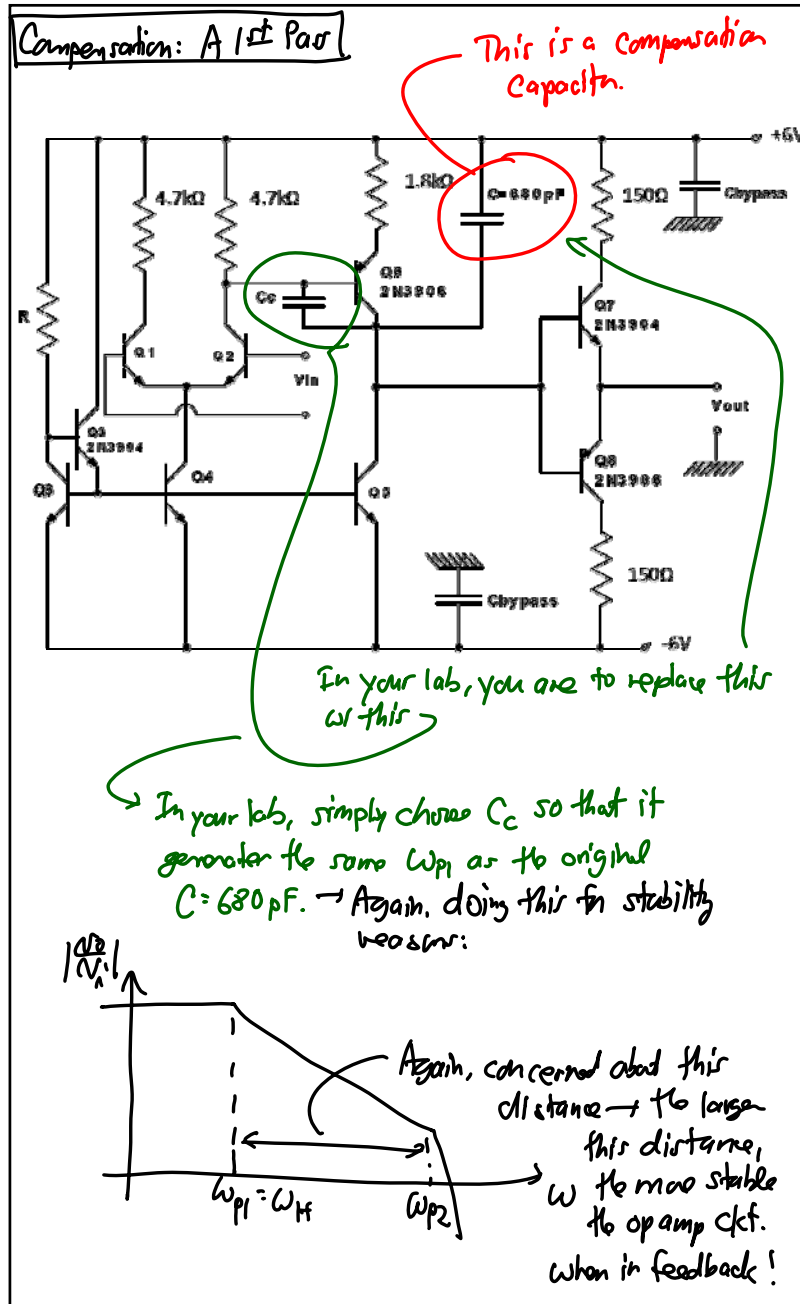


Remarks.

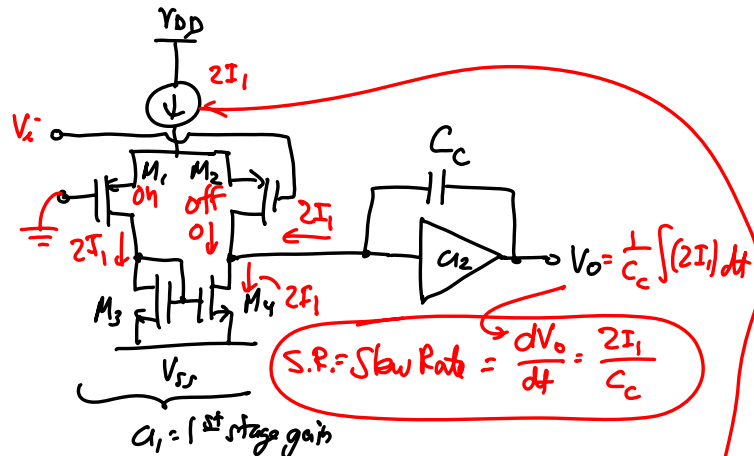
- ① You analyze this in Lab#2.
- ② Usually, the resistively-loaded diff. pair is replaced w/ an active current mirror load for more gain.
- ③  $R_{E6}$  raises the input R of  $Q_6$  (of the 2<sup>nd</sup> gain stage), plus helps w/ biasing.
- ④ Same comment as ③ for the output stage.
- ⑤ Output stage needed when driving a resistive load

often the case for bipolar  
not often the case for MOS, where a capacitive load  $C_L$  is often more relevant  $\rightarrow$  MOS op amps often don't need output stages!

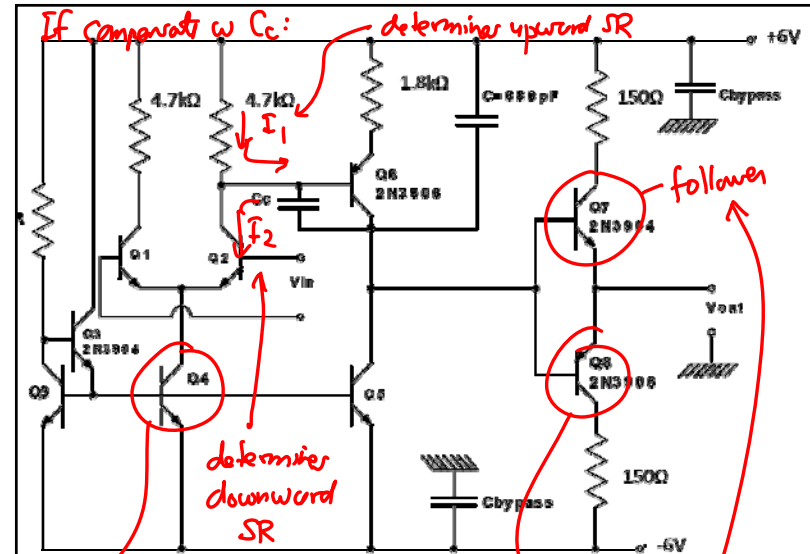
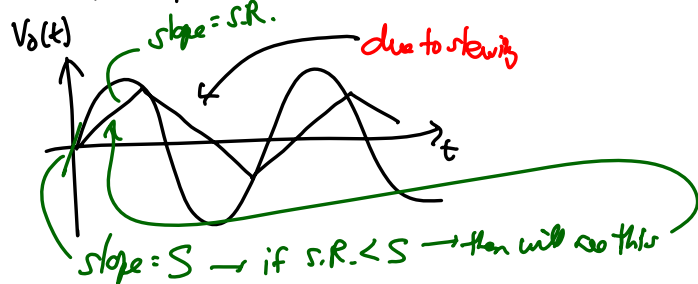
over  $\rightarrow$



Reason: 1<sup>st</sup> or 2<sup>nd</sup> stage of op amp cannot source enough current to mimic the slope (or speed) of a fast rising input signal.



If apply a very fast (i.e., high freq., large amplitude) sinusoid:



### Output Stages

- Class A (Emitter or Source Follower)
- Class B
- Class AB (we'll do this one later)

Purpose: Drive loads

- ① Deliver power w/ small distortion.
- ② Minimize output impedance → so that the amplifier gain is insensitive to the load.

Desirable Attributes:

- ① High  $R_{in}$ ; Low  $R_{out}$ .
- ② Low quiescent power.
- ③ Minimal effect on the amplifier freq. response.
- ④ Should be able to handle large input/output swings. (i.e.,  $V_i$  may be  $> V_T$ , invalidating small-signal approximations)

