Lecture 19: Compensation

- **Announcements:**
  - Solutions to midterm passed out
  - Graded midterms passed out
  - Lab#2 due this week → for M Lab → Tuesday @ 5p.m. ; for W Lab → Th @ 5p.m.
  - HW#9 online soon
  - Lab#3 online
- **Lecture Topics:**
  - Finish Stability
  - Compensation
- ------------------------------------
- **Last Time:**

Remarks:

① For the case of a single-pole op amp, FB w/ f = const. can never reach $\angle a(s)f = -180°$. (90° is the limit.)

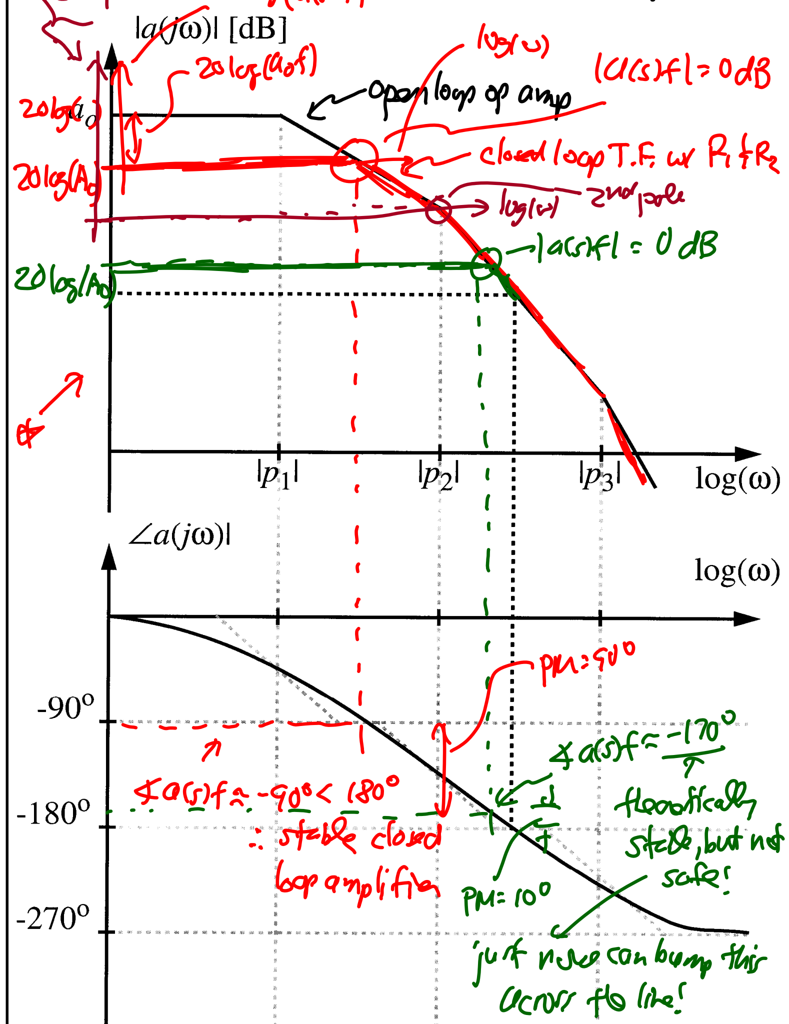
② Thus, a single-pole op amp in FB w/ f = const., i.e., f ≠ function of s = jω, is always stable!

But in reality, any op amp will have more than one pole → just two poles suff to $a(s)f = -180°$

three poles pass $a(s)f = -180°$ → Can instigate instability

Stability of a FB Ckt. Using a MultiPole Op Amp

Assume: dominant pole: p_1, non-dominant pole: p_2 & p_3 + $|p_3|, |p_4| \gg |p_2|$



For the general case where a(s) has multiple poles:

⇒ A(s) has the same additional poles (f = const.)

⇒ i.e., @ freq. > $|p_1|(1+a_o f)$, the A(s) curve just follows the a(s) curve:

$$A(s) \cong \frac{A_o}{\left(1-\frac{s}{|p_1|(1+a_o f)}\right)\left(1-\frac{s}{|p_2|}\right)\left(1-\frac{s}{|p_3|}\right)}$$

when $|p_1|(1+a_o f) < |p_2|$ (red curve) → *

↳ after this, get peaking

Definitions:

Phase Margin = $180^\circ + (\angle a(j\omega)f$ @ freq. where $|a(j\omega)f| = 1)$

= 90° (stable)

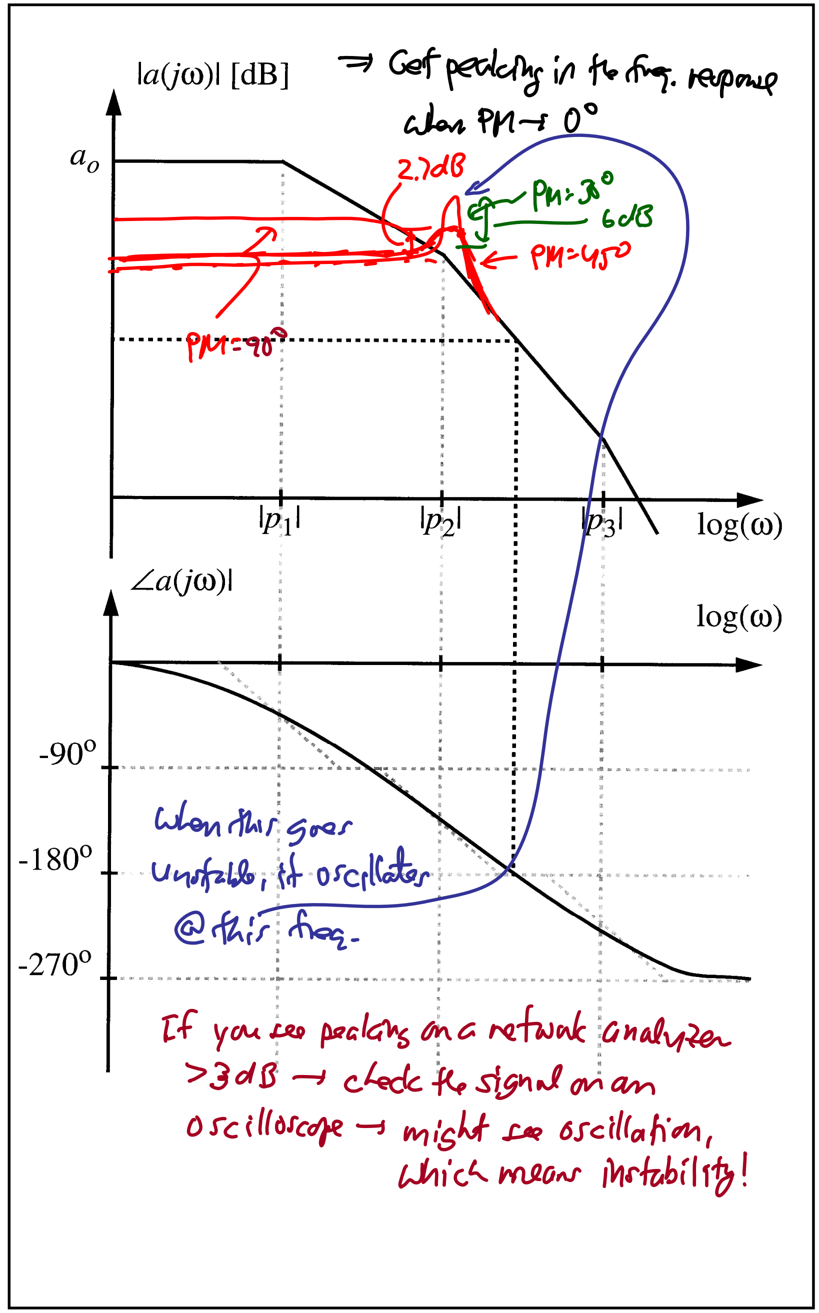
= 10° (stable, but very dangerous) → unstable

⇒ phase margin must be $> 0^\circ$ for theoretical stability

For Theoretical Stability, PM > 0°

⇒ for design safety, design for **Phase Margin ≥ 45°**

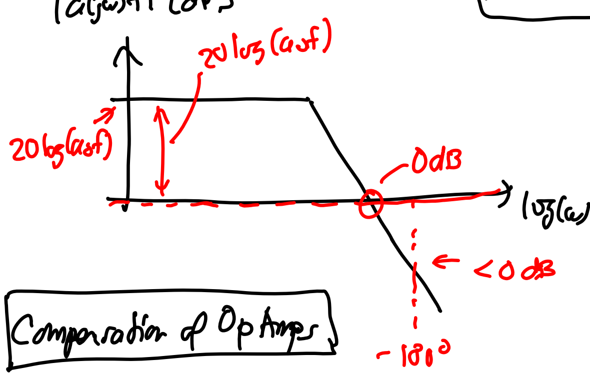
⇒ even safer (for settling time): **PM ≥ 60°**



Definition.

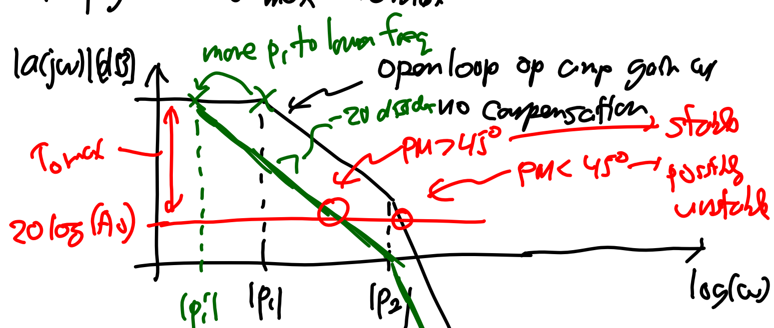
Gain Margin = $|a(j\omega)f|$ in dB @ freq. where $\angle a(j\omega)f = -180^\circ$

↳ For stability: Gain Margin < 0dB



Compensation of Op Amps

To compensate, make distance between p_1 & p_2 large enough to encompass the largest desired loop gain = $a_0 f_{max} = T_{o max}$



$20\log(T_{o max}) = -20(\log(p_2) - \log(p_1))$

$\frac{|p_2|}{|p_1|} = T_{o max} \rightarrow |p_2| = |p_1| T_{o max}$ — For PM ≈ 45°

Two Ways to Compensate:

1. Narrowbanding
2. Pole Splitting

Narrowbanding

"D": dominant

⇒ Introduce a pole p_D so that there is sufficient separation between p_D & p_1 → $\frac{|p_1|}{|p_D|} = T_{o max}$

↳ becomes the new second pole