Lecture 19: Compensation

- **Announcements**:
  - HW#8 online; due Wednesday next week
  - Lab#2 due this coming Wednesday at 5 p.m.
  - 240A students: HW#1A due Friday, Nov. 6
  - Lab#3 online
  - Midterms graded; hand back later today
- **Lecture Topics**:
  - Lab#3: Your Project
  - Finish Stability
  - Compensation
  - Pass out graded midterms and solutions

Prof. Nguyen Wed Office Hours → Friday, 10-11 a.m.

Lab#2 Due Monday Next week

Monday in lab lecture

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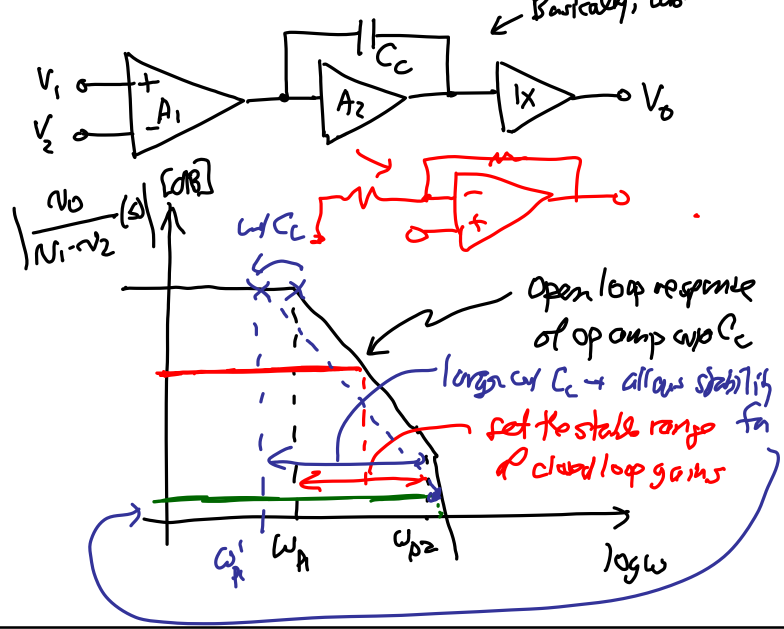
- **Last Time**:

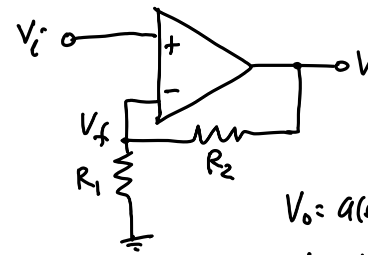
$\boxed{\text{Stability \& Compensation}}$

Basically, Lab#2.

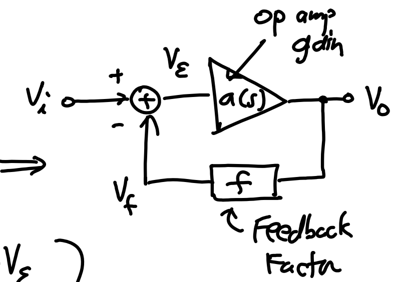


⇒ Problem: any FB loop can become unstable under certain conditions → ∴ must compensate to suppress instability!

Ex. Non-inverting Amplifier



⇒



$$\left.\begin{aligned} V_o &= a(s)V_\varepsilon \\ V_\varepsilon &= V_i - V_f \\ V_f &= fV_o \end{aligned}\right\} V_o = a(s)(V_i - fV_o)$$

$$\underbrace{A(s)}_{\text{closed loop gain}} = \frac{V_o}{V_i}(s) = \frac{a(s)}{1+a(s)f} = \frac{a(s)}{1+T(s)}$$

Loop Transmission $= T(s) = a(s)f$ ↳ fcn of freq.

e.g., loop gain $= a(j\omega = 0)f = a_o f = T_o$

Instability occurs when $A(s) \to \infty$!

$$\Rightarrow A(s) = \frac{a(s)}{1+a(s)f} \to A(s) = \frac{a(s)}{1-1} = \frac{a(s)}{0} \to \infty$$

$\underbrace{a(s)f}_{\text{loop transmission}} = -1$

will also go unstable if denominator is (−)

In General:

$\boxed{\text{If } |a(s)f| \geq 1 \text{ when } \measuredangle a(s)f = -180^\circ \Rightarrow \text{unstable}}$

This is a simplified form of the Nyquist criterion.

Stability of a FB Ckt. Using a Single-Pole Op Amp

For a single-pole op amp: $a(s) = \dfrac{a_o}{1 - \frac{s}{p_1}}$ = open-loop op amp Xfer Fcn.

Thus: (close the loop)

$$A(s) = \frac{a(s)}{1 + a(s)f} = \frac{a_o}{1 + a_o f} \cdot \frac{1}{1 - \frac{s}{p_1(1 + a_o f)}}$$

$A(s)$ = closed-loop Xfer Fcn

$\frac{a_o}{1+a_o f}$: A_o = closed-loop dc gain, if $a_o f >> 1 \rightarrow \approx \frac{1}{f}$

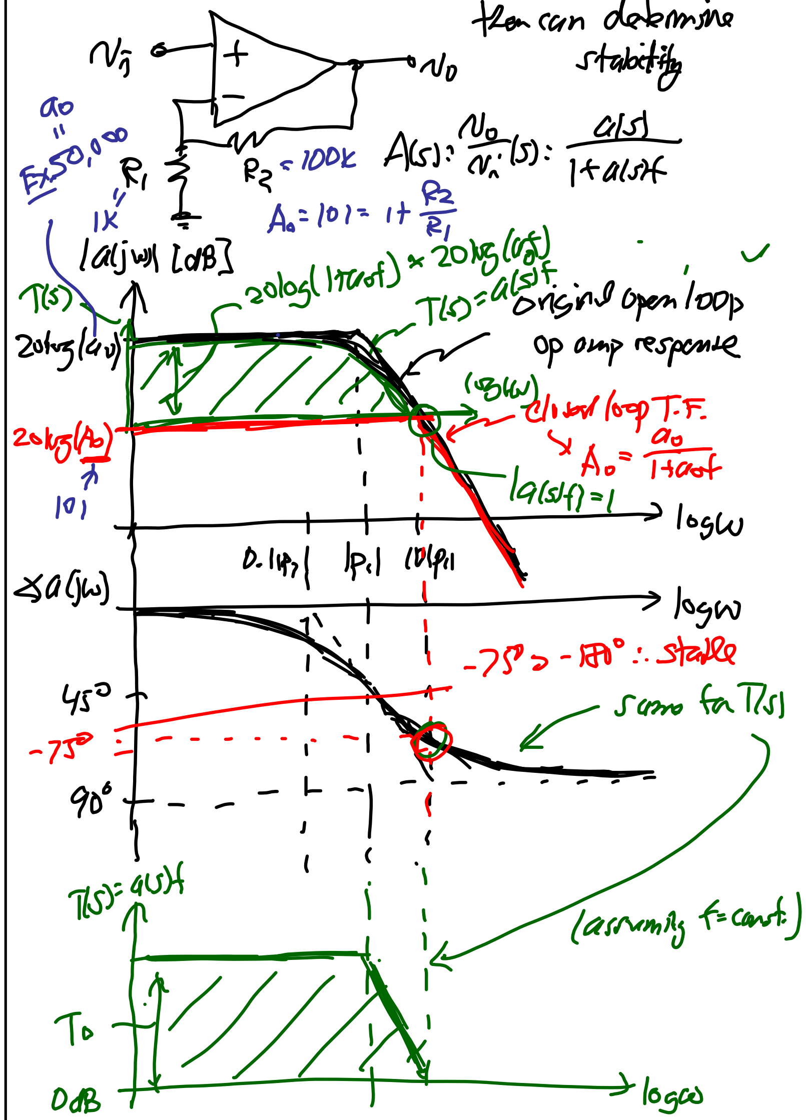
$p_1(1+a_o f)$: BW increases by $1 + a_o f$

$T_o = a_o f$ = loop gain (defined @ DC)

$T(s) = a(s)f$ = loop transmission (defined for general freqs.)

Bode Plot: → use to determine $\measuredangle a(s)f$ when $|a(s)f| = 1 = 0\,\text{dB}$

then can determine stability



Remarks:

w/ f = const

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

② Thus, a single-pole op amp in FB w/ f = const., i.e., $f \neq$ function of $s = j\omega$, is always stable!

↓

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

↓

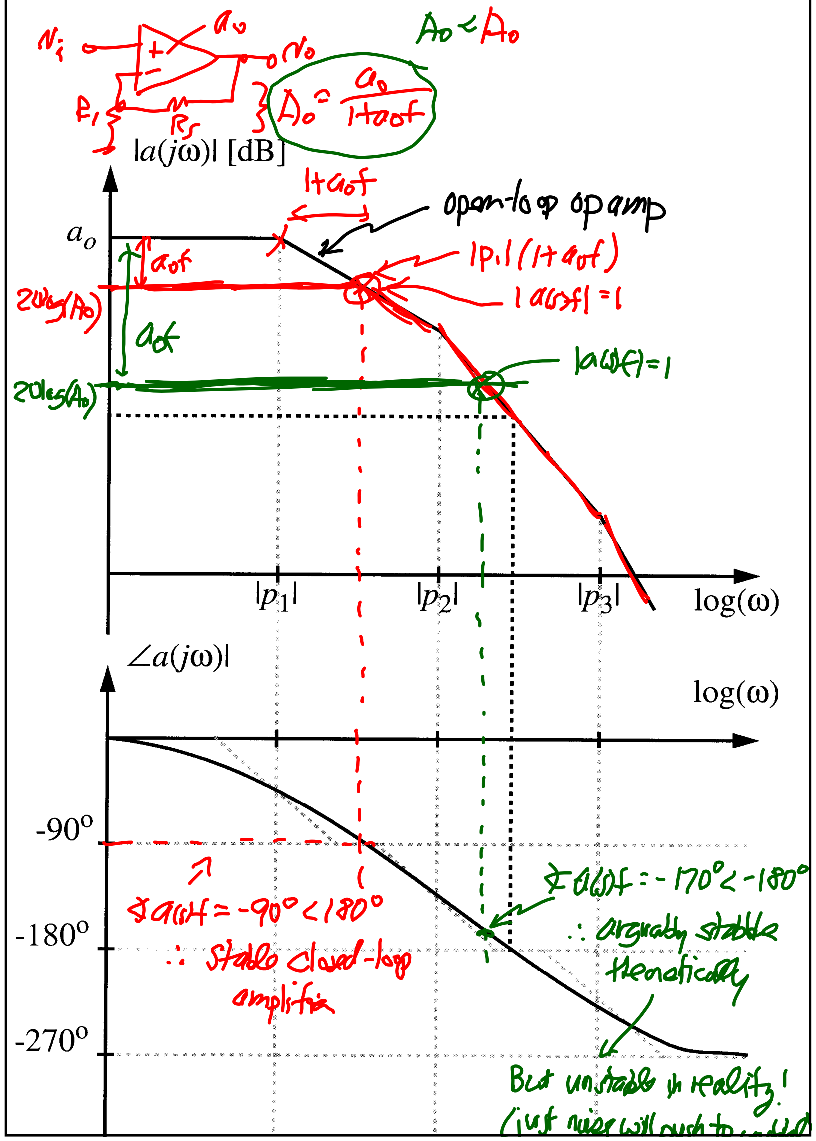
instigate instability

↓

Use a Bode plot to investigate

Stability of a FB Ckt. Using a Multi-Pole Op Amp

Assume: dominant pole: p_1, non-dominant poles: p_2 & p_3 +



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

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

⇒ i.e., @ freqs. > $|p_1|(1+a_of)$, the A(s) curve just follows the a(s) curve (provided the new p_1' is not too close to the original p_2)

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

when $|p_1|(1+a_of) < |p_2|$

↳ after p_2, get peaking