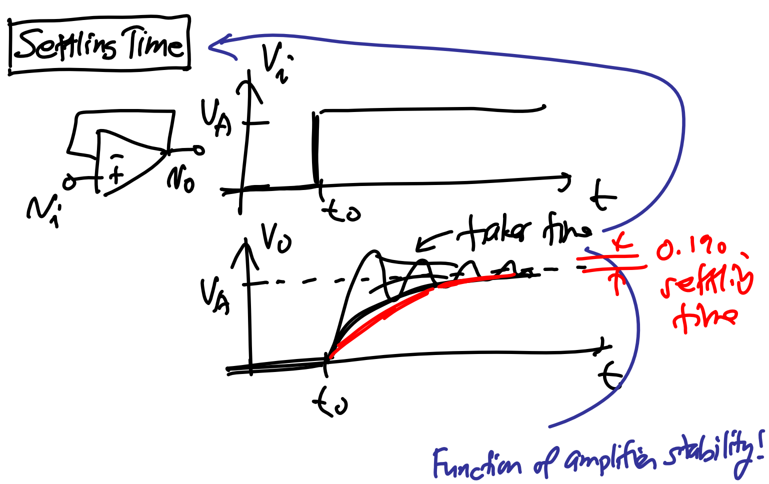
Lecture 17: Output Stages

- **Announcements:**
  - Midterm's graded – will pass back at the end of lecture
  - HW#9 will be online on Thursday
  - Lab#2 due this Friday
    - Grade depends heavily on the report
    - Make sure you spend enough effort on the report per your TA's requirements
  - Lab#3 update online (update for 240A folks)
  - No lecture next Tuesday – we will make this up by going 2 hours the next three lectures
- **Lecture Topics:**
  - Stability
- ------------------------------------
- **Last Time:**



Stability & Compensation in Op Amps → can cause instability!

In general, op amps are used in neg. FB loops.

Reasons:

① Feedback sets the biasing → no large coupling or bypass caps needed.

② FB increases BW.

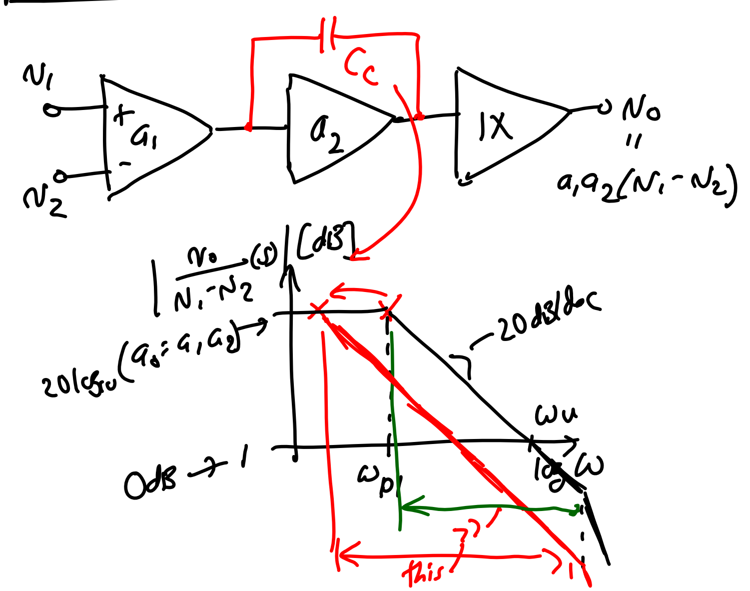
③ FB increases linearity or input range. (e.g., emitter degeneration is a type of FB)

④ Gain determined by external FB components → more accurate than op amp gain.

⑤ FB sets R_i and R_o.

⑥ FB can improve temperature stability.

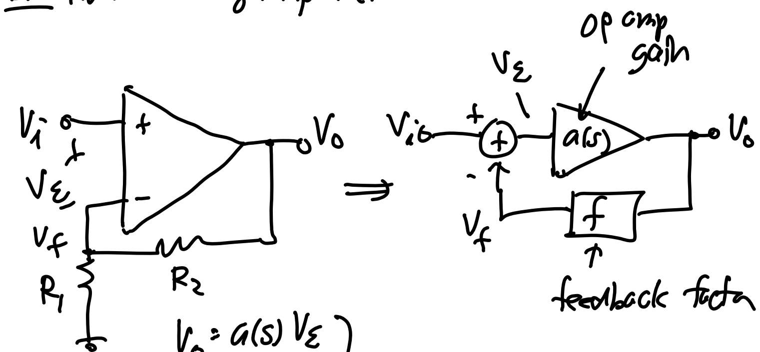
Stability & Compensation



Where does instability come from? — practical

⇒ any neg. FB becomes unstable under certain conditions → ∴ must compensate to suppress instability!

Ex. Non-Inverting Amplifier



$V_o = a(s) V_\varepsilon$
$V_\varepsilon = V_i - V_f$
$V_f = f V_o$

$\} \; V_o = a(s)(V_i - f V_o)$

$$A(s) = \frac{V_o}{V_i}(s) = \frac{a(s)}{1+a(s)f} = \frac{a(s)}{1+T(s)}$$

↑ closed loop gain

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

@ dc: loop gain $= a_o f = T_o$

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

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

↑ $a(s)f = -1$ → will also go unstable if denominator is (−)

In General:

If $|a(s)f| \geq 1$ when $\measuredangle a(s)f = -180°$ } ⇒ Instability

↑ 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: $a(s) = \frac{a_o}{1 - \frac{s}{p_1}}$ ≡ op amp transfer function

Thus: closed loop T.F.

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

A_o: closed loop dc gain ↘ $(1+a_o f)$ smaller than a_o $\approx \frac{1}{f}$

Freq. Shaping Term ← BW increases

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

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

Bode Plot: → use to determine $\measuredangle a(s)f$ when $|a(s)f| = 1$ → then can determine stability