Lecture 18: Stability

Announcements:
1. Lab#2 due week of 3/19 (next week) which is one week after the original due date
2. Suggestion: Get it done this week
3. Midterm Exam next Thursday, 3/22
4. Review Session: Monday, 3/19, 7-9 p.m., Hogan Room (521 Cory)

Lecture Topics:
- Midterm information
- Output Stages (continued)
- Stability

Last Time: [Emilia, Fallona (Clara)]

Two main cases:
1. \( I_o > 0 \) (\( I_o \) flows through \( Q_1 \))
   - \( I_o \) must be sunk to \( V_{EE} \) through \( R_E \)
   - \( I_o, \frac{V_o - V_{EE}}{R_E} \rightarrow |I_o| \) gets smaller as \( V_o \) decreases
   - Problem!

2. \( I_o < 0 \) (i.e., \( V_o < 0 \))
   - \( I_o \) must be sunk to \( V_{EE} \) through \( R_E \)

Solution: Replace \( R_E \) with a current source.

\[ V_{CC} \]
\[ V_o \]
\[ I_{BAS} \]
\[ V_{EE} \]

\[ V_E \]

\[ R_4 = \frac{1}{g_m} \]

Actual Implementation:

\[ V_{CC} \]
\[ V_{EE} \]
\[ V_{be1} \]
\[ V_{be2} \]

\[ V_o = V_{o1} + V_{be1} \]

\[ V_{be1} \neq V_{be2} \]

\[ R_4 \]

\[ V_{be1} \]

\[ V_{be2} \]

\[ V_{be1} \]

\[ V_{be2} \]

\[ V_{be1} \]

\[ V_{be2} \]
For $V_i := \text{large and } (+) : V_o \text{ follow } V_i \text{ until } Q_2 \text{ saturates} $

$$V_{\text{min}} = V_{EE} + V_{CE2(sat)} \quad \text{or} \quad V_i = V_o + V_{BE1} = V_{EE} + V_{CE2(sat)} + V_{RE1}$$

Case 2: $R_e \text{ small} \Rightarrow \text{Thus, } I_o \text{ can be large!}$

For $V_i := (+) \text{ and large}: Q_i \text{ can source as much current as needed until it saturates (or it dies)}$

For $V_i := (-) \text{ and large}: V_o + I_o R_e \rightarrow \text{ min, } V_o = -I_o R_e$

$\Rightarrow Q_i \text{ cut off } (I_{C1} = 0)$

$\Rightarrow V_o \text{ clamps at } -I_o R_e$

Fix by making $I_o \text{ large}$

$\text{Problem: too much power consumption}$

$$P_o = (V_{EE} - V_{BE}) I_o \quad \text{DC power consumption!}$$

$V_{EE} := (-) \text{ Clamps, if you want a large output swing w/ } R_e \text{ small,}$

you must consume power!
Solution: Class B Output Stage

V can attain zero DC (no quiescent power)

\[ V_{cc} \]

\[ Q_1 \]

\[ V_i \]

\[ Q_2 \]

\[ V_{ee} \]

Initial \( V_o = 0V \)

For \( V_o = 0V \) → no DC power consumption!

Operation:

\[ V_i < V_{BEC(m)} \rightarrow I_{E1} = I_{E2} = 0 \rightarrow V_o = 0V \]

\[ V_{cc} > V_i > V_{BEC(m)} \rightarrow V_o \approx V_i - V_{BEC(m)} \]

\[ V_{omax} = V_{cc} - V_{BEC(m)} \], \[ V_{omin} = V_{ee} + V_{CE2(cut)} \]

\[ V_{cc} - V_{BEC(m)} \]

\[ V_i \]

\[ V_{ee} + V_{CE2(cut)} \]

Problem: Dead Zone.

To remove distortion due to the dead zone → compromise: Class AB

\[ 2V_{BEC(m)} \]

\[ \text{Thus keep } Q_1 \text{ & } Q_2 \text{ on, but use less DC power consumption than Class A} \]
Stability in Comparison

\[ V_1 \rightarrow a_1 \rightarrow a_2 \rightarrow a_3 \rightarrow V_0 \]

- \[ C_c \] Compensation Capacitor
- \[ q, qa_2(V_1 - V_2) \]
- Used to set BW.
- Why is \[ C_c \] needed?

Stability in Compensation in Op Ams

- In general, op amps are used in reg FB loops.
- Reason:
  1. Feedback set the biasing and large coupling or bypass is needed.
  2. FB increases BW.
  3. FB increases linearity of Input range.
   (e.g., emitter degeneration is a type of FB)
  4. Gain determined by external FB components is more accurate than op amp gain.
  5. FB sets \( R_i \) and \( R_o \).
  6. FB can improve temperature stability.

-- Problem: any FB loop can become unstable under certain conditions.
- Need to compensate the instability.

Ex. Non-Inverting Amplifier

\[ V_i \rightarrow + \rightarrow 0 \rightarrow \rightarrow V_o \]

- \( V_o = a(s) V_o \)
- \( V_o = V_i - V_o \)
- \( V_o = a(s)(V_i - fV_o) \)

Closed Loop

- Voltage Gain
- Loop Transmission

- Instability occurs when \( A(s) \rightarrow \infty \).
- \[ A(s) = \frac{a(s)}{1+a(s)f} \rightarrow A(s) \rightarrow \infty \]
- \[ A(s) \rightarrow -1 \] will also go unstable when denominator = (-)
If \( |a(s)| \leq 1 \) when \( a(s) \rightarrow -180^\circ \), then the system is unstable.

This is just a simplified form of the Nyquist Criterion.