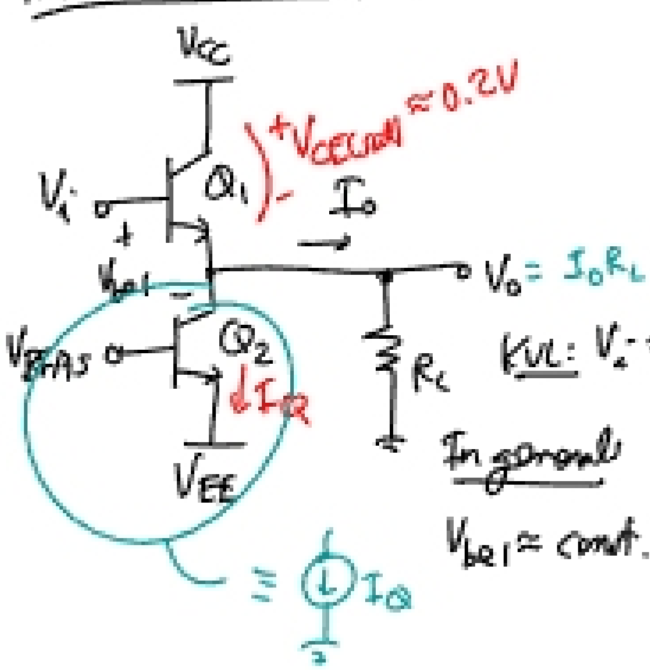
Lecture 19: Stability

- Announcements:
  - This is our make-up lecture, which replaces tomorrow's (Thursday's) lecture, since I will be traveling on Thursday
  - Again, I will be using software local to my computer to record the lecture
- Lecture Topics:
  - Finish Output Stages
  - Stability
  - Single-Pole Op Amp in Feedback
  - Multi-Pole Op Amp in Feedback
  - Phase Margin
- ------------------------------------
- Last Time:

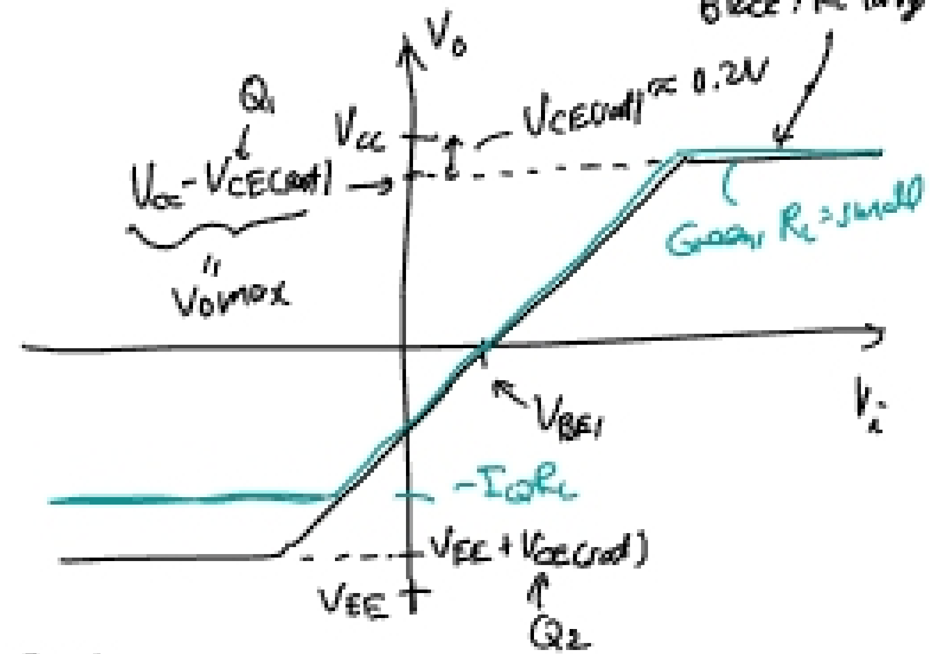
Actual Implementation



KVL: $V_i = V_o + V_{be1}$

In general:

$V_{be1} \approx$ const. $\rightarrow V_T \ln\left(\frac{I_{c1}}{I_{s1}}\right)$



Two Cases:

Case ①: R_L = large → $I_o < I_Q$

⇒ I_o not Δ'ing much to get a large ΔV_o

For V_i = large and (+): Q_1 must source $I_o + I_Q$ to make $V_o \uparrow$

→ at some pt., Q_1 will saturate as $V_o \uparrow$

→ $V_{omax} = V_{CC} - V_{CE(sat)}$

→ and $V_i = V_{CC} - V_{CE(sat)} + V_{BE1}$

not always possible if input signal is limited by V_{CC} supply rail

For V_i = large and (−): V_o follows V_i until Q_2 saturates

$V_{omin} = V_{EE} + V_{CE(sat)}$ ← of Q_2

$V_i = V_o + V_{BE1} = V_{EE} + V_{CE2(sat)} + V_{BE1}$

Case ②: R_L = small → thus, I_o can be large!

For V_i = (+) and large: Q_1 can source as much current as needed until it saturates (or until it fries)

For V_i = (−) and large: $V_o = I_o R_L$ → min. $V_o = -I_Q R_L$

→ Q_1 cuts off ($I_{C1} = 0$)

→ V_o clamps @ $-I_Q R_L$

→ further decrease in V_i → no Δ in V_o!

Soln: raise I_Q to set to $V_{EE} + V_{CE(sat)}$, if desired

↓

Problem: Need large I_Q → DC current ← always there, whether or not there is a V_i

↓

always have DC power cons.!

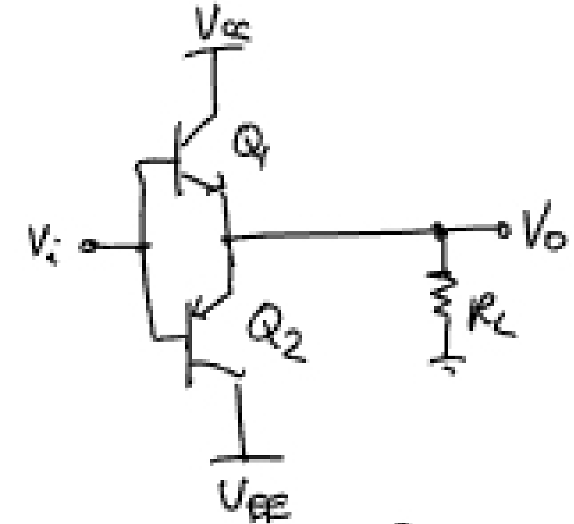
↳ often, too much!

$P_Q = (V_{CC} - V_{EE}) I_Q$

↖ quiescent DC → large DC power consumption! Bad!

Solution: Class B Output Stage

↳ can attain zero quiescent (DC) power

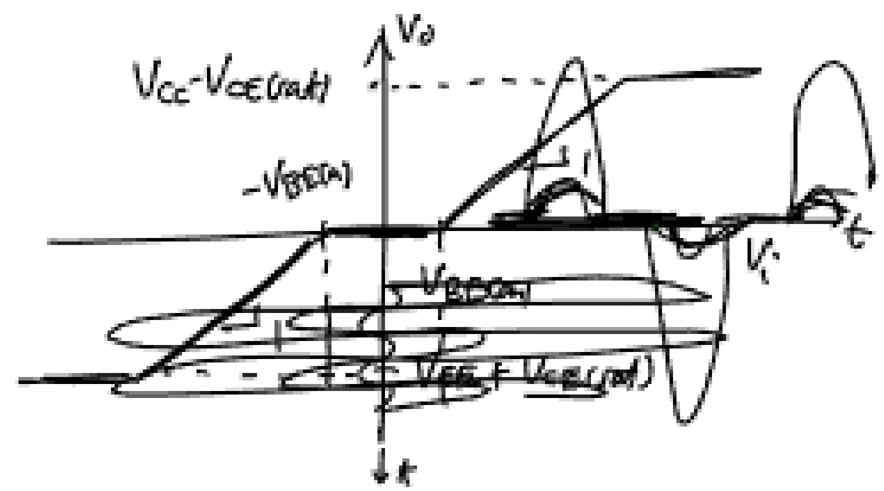


Operation: (zero power consumption)

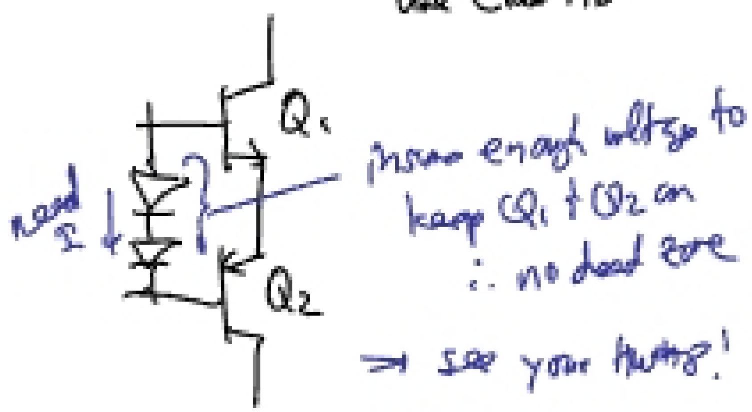
$|V_i| < V_{BE(on)}$ → $I_{E1} = I_{E2} = 0$ → $V_o = 0V$

$V_{CC} > V_i > V_{BE(on)}$ → $V_o \cong V_i - V_{BE(on)}$ Q_1 on; Q_2 off

$-V_{BE(on)} > V_i > V_{EE}$ → $V_o \cong V_i + V_{BE(on)}$



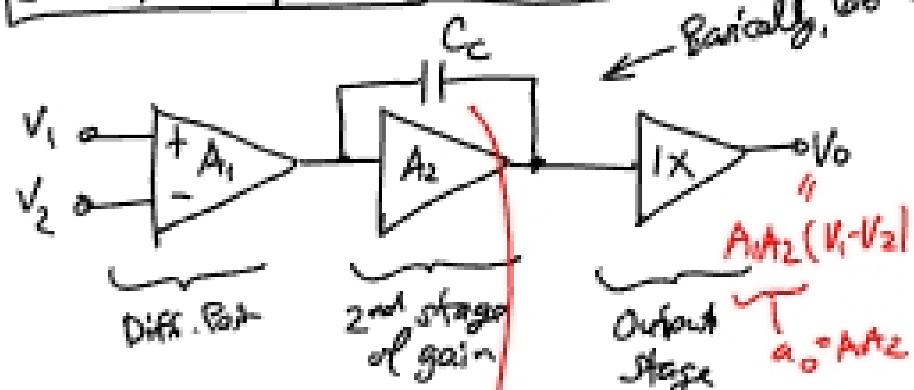
To solve the dead zone (while maintaining low DC bias currents): use Class AB



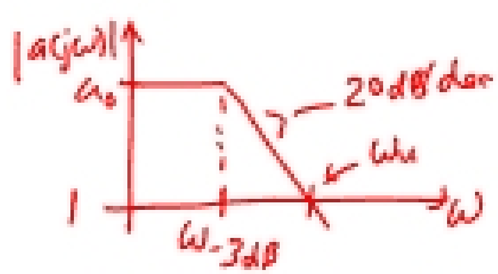
⇒ see your HW #8!

Stability & Compensation in Op Amps

Basically, lab #2.



Used C_c to set BW:



Why use C_c? → stability!

Stability & Compensation in Op Amps

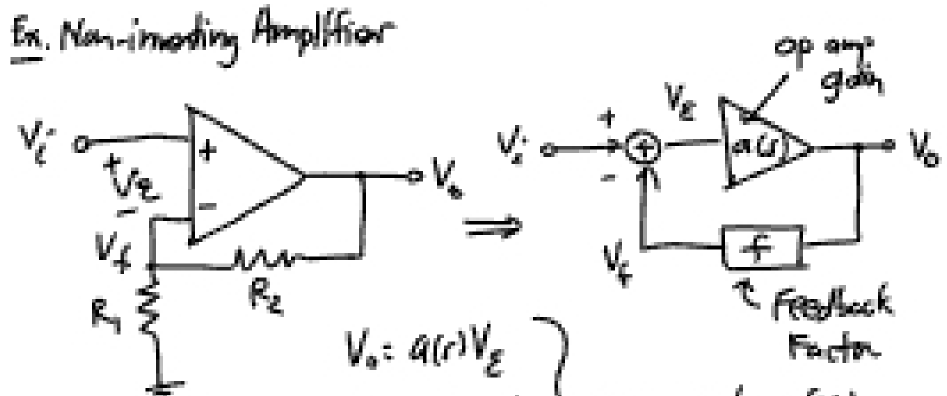
In general, op amps are used in neg. FB loops. ← neg. FB, if not really neg. FB, can cause instability

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.

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

Ex. Non-inverting Amplifier



$V_o = a(s)V_\varepsilon$, $V_\varepsilon = V_i - V_f$, $V_f = fV_o$ } $V_o = a(s)(V_i - fV_o)$

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