Single vs. Multi-Stage
Stability for Simple 2-Stage Amp

- Two (closely spaced) poles - is this circuit stable?

Compensation Techniques

- Many options – best one depends on situation at hand

- Look at a few general categories:
  - Narrowbanding
  - Miller
  - Advanced Miller
Narrowbanding

- Narrowbanding
  - Lower one of the poles
  - Or introduce a new one

- Stability OK, but (feedback)
  GBW limited by second pole

Miller Compensation
Not Quite That Simple…

Why Right-Half Plane Zero?
Effect on Stability

Nulling Resistor

- $R_z$ limits feedforward current at high frequency
- Pushes feedforward zero to higher frequency
- Adds new pole $p_3$

$$z \rightarrow \frac{1}{g_{m2}} \frac{g_{m2}}{(1 - g_{m2}R_z) C_c}$$

$p_1, p_2$: no change

$$p_3 \approx \frac{1}{R_z C_1}$$
Choice of $R_z$

Cascode Compensation (Ahuja)

- No RHP zero
- But cost in power can be high
  - ($I_2$ needs to slew $C_c$)
Cascode Compensation (Ribner)

Noise Analysis

- Need a simplified model:
Noise Analysis cont’d

\[ v_o = \frac{1}{ \frac{1}{Fg_{m1}} + \frac{1}{\omega_b Q} + \frac{s^2}{\omega_b^2} } \left( i_{n1} - i_{n2} \frac{s C_c}{g_{m2}} \right) \]

with

\[ \omega_b^2 = \frac{Fg_{m1} g_{m2}}{C_c (C_c + C_L)} \]

\[ \omega_b Q = \frac{Fg_{m1}}{C_c} \]

Total Noise at Output

\[ \overline{v_{oT}^2} = \frac{k_B T}{C_c} \gamma \frac{1}{F \left( \frac{C_c + C_L}{C_c} \right)^\gamma} \]

\[ \overline{v_{oT}^2} = \frac{k_B T}{C_c} \gamma \left( 1 + \frac{F C_c}{C_c + C_L} \right) \]

- Noise from first stage dominates
- Noise capacitor: \( C_c \) (NOT \( C_L \)!)
Design Methodology

- **Integrated noise limited:**
  - \( g_{m2} = K^*\omega_u^*C_L \), \( K \) chosen by settling or stability
  - \( C_c = \frac{-kT}{(F*\nu_c^2)} \)
  - \( g_{m1} = C_c^*\omega_u/F \)

- **GBW-limited:**
  - \( g_{m2} = K^*\omega_u^*C_L \), \( K \) chosen by settling or stability
  - Make \( g_{m1} \) and \( C_c \) as small as possible (while making sure \( A_{\nu 2}^*C_c > C_1 \))

- **“Noise density” limited:**
  - \( g_{m2} = K^*\omega_u^*C_L \), \( K \) chosen by stability
  - Find \( g_{m1} \) based on noise density/SNR constraint
  - Size \( C_c \) based on \( \omega_u \)
  - (May need to iterate/upsize \( g_{m1} \) to include effect of \( g_{m2} \) noise at edge of band)