EE 240B – Spring 2018

Advanced Analog Integrated Circuits
Lecture 11: Multistage OTA Design

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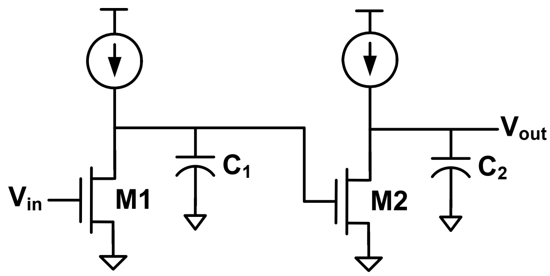
Single vs. Multi-Stage

Stability for Simple 2-Stage Amp



p1 = **p2 =**

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

Compensation Techniques

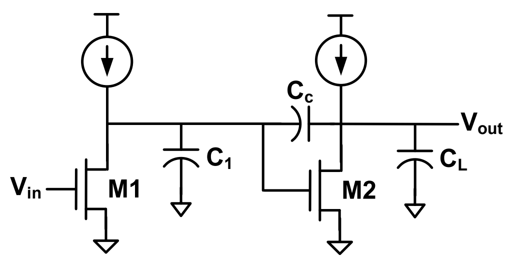
- **Many options – best one depends on situation at hand**
- **Look at a few general categories:**
  - Narrowbanding
  - Miller
  - Advanced Miller

Narrowbanding

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

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

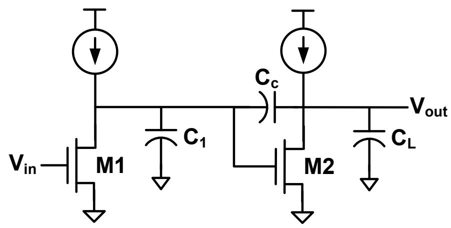
Miller Compensation



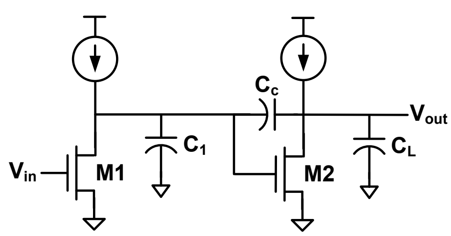
Pole Splitting

Miller Compensated Poles

Not Quite That Simple…

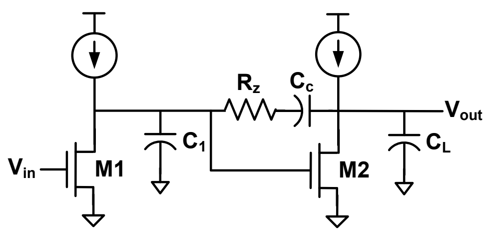


Why Right-Half Plane Zero?



Effect on Stability

Nulling Resistor



$$z \to \frac{1}{(1-g_{m2}R_Z)}\frac{g_{m2}}{C_c}$$

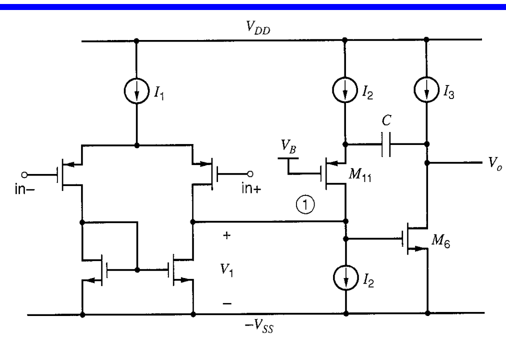
$$p_1, p_2: \quad \text{no change}$$

$$p_3 \approx -\frac{1}{R_z C_1}$$

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

Choice of Rz

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

$$v_o = \frac{1}{Fg_{m1}} \frac{1}{1+\frac{s}{\omega_o Q}+\frac{s^2}{\omega_o^2}} \left(i_{n1} - i_{n2}\frac{sC_c}{g_{m2}} \right)$$

with

$$\omega_o^2 = \frac{Fg_{m1}g_{m2}}{C_c(C_c+C_L)}$$

$$\omega_o Q = \frac{Fg_{m1}}{C_c}$$

Total Noise at Output

$$\overline{v_{oT}^2} = \frac{k_B T}{C_c}\frac{\gamma}{F} + \frac{k_B T}{(C_c+C_L)}\gamma$$

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

- **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
  - $C_c = \sim kT\gamma/(F*v_o^2)$
  - $g_{m1} = C_c*\omega_u/F$

- **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 $A_{v2}*C_c > C_1$)

Design Methodology

- **"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 ω_u
  - (May need to iterate/upsize g_{m1} to include effect of g_{m2} noise at edge of band)