Residue Stage Op-amp

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Outline

• Why Single Stage op-amp
• Review basic equations
• Single-stage architecture
  • Folded Cascode OTA
  • Telescopic OTA
• Simulation results
• Conclusion
OTAs with Single-Gain Stage

- OTAs with a signal gain stage have been widely employed in SC circuits.
- Single Stage Architecture offers larger bandwidth and good phase margin
- A high output impedance provides adequate gain.
- No frequency compensation is needed.
- Self Compensation (dominant pole is determined by load cap).
Review of basic equation dealing with Single-Stage op-amp

- The dc gain

\[ A_v = G_m * R_{out} \]

\[ G_m \approx g_m(\text{for input device}) \]

- GBW

\[ \omega_t \approx \left( \frac{g_m 1}{C_{load}} \right) \]
• Slew rate

\[ SR = \left( \frac{I_D}{Cl} \right) \]

• Settling Time

– The op-amp bandwidth and the slew rate limit the settling time.
– For a small step the settling rate depends only on the unity bandwidth.

\[ \tau = \left( \frac{1}{\beta \ast \omega_t} \right) \]
Folded Cascode OTA
NMOS or PMOS Input Devices?

- NMOS Inputs Means PMOS Cascode
  - NMOS offers larger GBW (gm1/CL) and higher gain, but decreases the PM.

- PMOS Inputs Means NMOS Cascode
  - Lower GBW and gain, but good PM (non-dominant pole is higher).
Advantages

• Provides a larger output swing and input CM range than telescopic.

• The output swing,
  \[2V_{\text{sup}} - 8V_{ds,\text{sat}} - 4V_{m \text{arg in}}\]

• The input CM range,
  \[V_{DD} - V_{th} - 2V_{ds,\text{sat}}\]
Disadvantages

- Lower gain compared to the telescopic cascode due to lower output impedance.

\[ A_v = G_m \times R_{out} \]
\[ A_v = g_{m1} \times \left( g_{m8} \times r_{o8} \times r_{o1//r_{o10}} \right) / R_{op} \]
• The folding point contributes more parasitics and leads to lowering the non-dominant pole.

• Higher noise

• Higher power dissipation
Advantages

• Higher frequency capability
  – Its second pole is determined by transconductance of n-channel devices as opposed to p-channel, as in the case of a folded cascode. Also, the parasitic capacitance at this node arises from only two transistor instead of three.

• Higher gain due to higher output resistance.
Disadvantages

• The disadvantage of telescopic is the limited output swing.

• It is smaller than that of the folded because the tail transistor directly cuts in to the output swing.

• The out swing is limited to

  \[2V_{\text{sup}} - 10V_{ds, \text{sat}} - 6V_{m \text{ arg in}}\]
Conclusion

• At large supply voltage, the telescopic architecture becomes the natural choice for system requiring moderate gain.

• Reducing the power supply, on the other hand, forces reconsideration in favor of folded cascode.