Lecture 10
IL2218 Analog electronics, advanced course

• Ch 9 Operational amplifiers
  – One stage OP amps
  – Folded Cascode OP amps
  – Design example 9.6
  – Two stage OP amps

• Ch 10 Stability
  – Multipole systems
  – Phase margin

Telescopic Cascode Op Amps

Drawbacks:
Limited output swing
Problem to short input and output

\[ V_{\text{max}} - V_{\text{min}} = V_{TH4} - (V_{GS4} - V_{TH2}) \]

Maximized by minimizing the overdrive of M4, but always less than V_{TH2}
Folded Cascode Amplifier

The small signal current generated by M1 flows through M2 and the load

$A_v \approx g_{m1}R_{out}$

Folded Cascode Op Amps

(a) (b)

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Folded Cascode Op Amps

Why, so many transistors?

Swing

Lower end \( V_{OD3} + V_{OD5} \)

Upper end \( V_{DD} - (|V_{OD7}| + |V_{OD9}|) \)

\[
|A_v| \approx g_{m1} \left\{ \left( g_{m3} + g_{mb3} \right) r_{o3} (r_{o1} \parallel r_{o3}) \right\} / \left\{ \left( g_{m7} + g_{mb7} \right) r_{o7} r_{o9} \right\}
\]

Compared to telescopic: Lower gain, pole at lower frequency

Design example 9.6

Study the example, compare with example 9.5!
Two-Stage Op Amps

In high gain amplifiers, we wish a $p$-type current source to balance a $n$-type current source.

Mismatches can drive $p$-type or $n$-type current source into triode region.

If the output CM level requires calculation on device properties, then it is poorly defined.
Stability (chapter 10)

\[ \frac{Y(s)}{X(s)} = \frac{H(s)}{1 + \beta H(s)} \]

May oscillate at \( \omega \) if \( |\beta H(j\omega)| = 1 \) and \( \angle \beta H(j\omega) = -180 \) (Barkhausen criteria)

Unstable and Stable Systems

Bode plot for open loop system, poles and zeroes for loop gain
Phase margin

Loop gain

Closed loop gain

Phase margin and step response

45° phase margin

Step response in time domain
Location of system poles

Stability can be studied by plotting the location of poles of the closed loop system.

One-pole system

Construct the root locus for this system!
Two-pole system

Construct the root locus for this system!

Three-pole system

Next lecture: Compensation methods, example 10.11