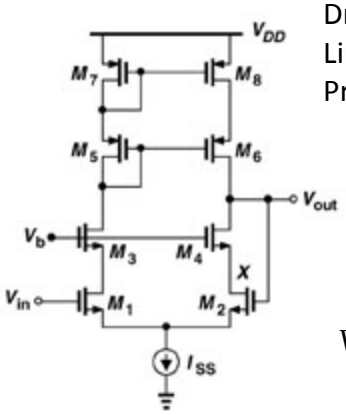
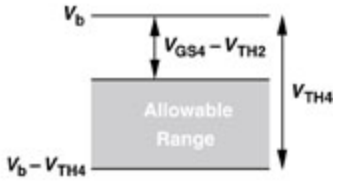
Lecture 10
IL2218 Analog electronics, advanced course

- 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



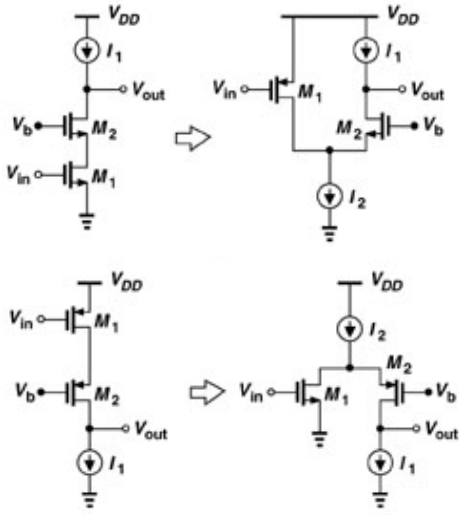
Drawbacks:
Limited output swing
Problem to short input and output



$$V_{\max} - V_{\min} = V_{TH4} - (V_{GS4} - V_{TH2})$$

Maximized by minimizing the overdrive of M_4, but always less than V_{TH2}

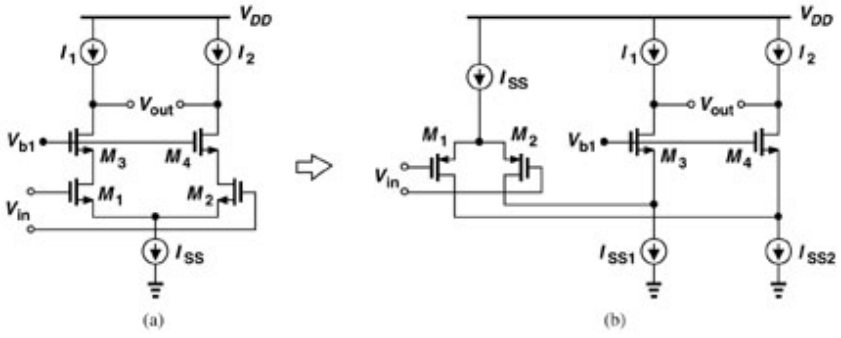
Folded Cascode Amplifier



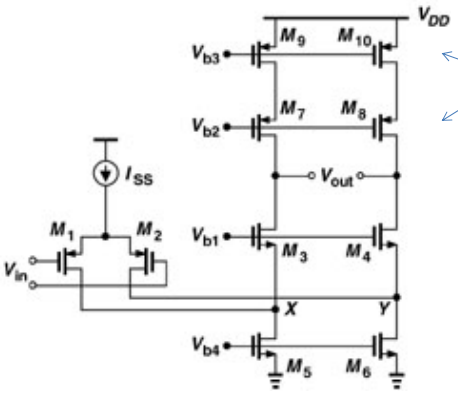
The small signal current generated by M_1 flows through M_2 and the load

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

Folded Cascode Op Amps



Folded Cascode Op Amps



Why, so many transistors?

Swing

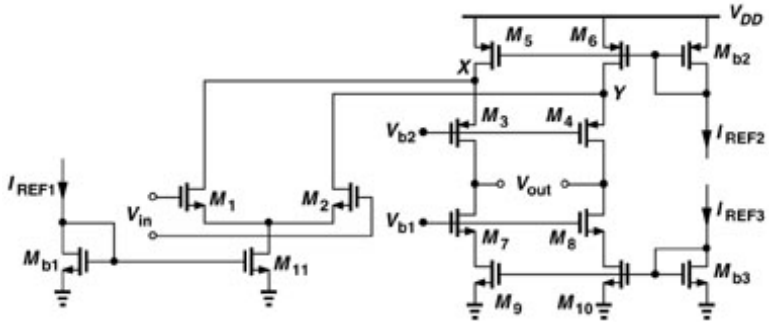
Lower end $V_{OD3} + V_{OD5}$

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

$$|A_v| \approx g_{m1}\{[(g_{m3} + g_{mb3})r_{o3}(r_{o1} \| r_{o5})] // [(g_{m7} + g_{mb7})r_{o7}r_{o9}]\}$$

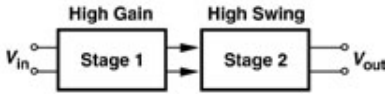
Compared to telescopic: Lower gain, pole at lower frequency

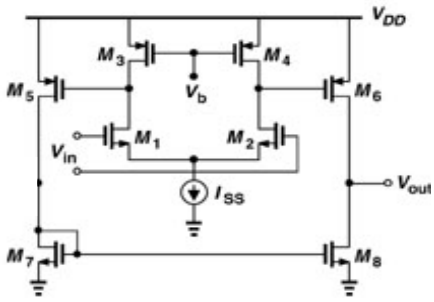
Design example 9.6



Study the example, compare with example 9.5!

Two-Stage Op Amps



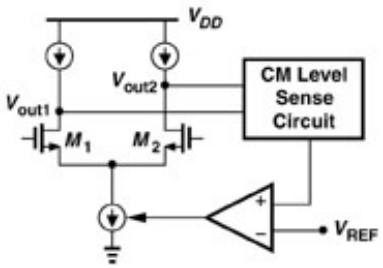


Gain= ?

Common Mode Feedback

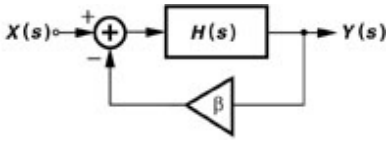
In high gain amplifiers, we wish a *p*-type current source to balance a *n*-type current source.

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)

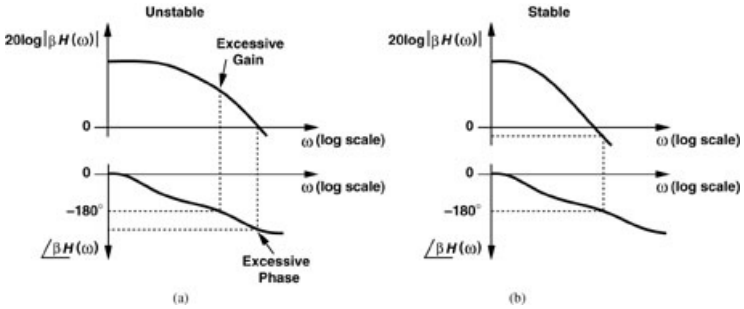


$$\frac{Y}{X}(s) = \frac{H(s)}{1+\beta H(s)}$$

$$May\ oscillate\ at\ \omega\ if\ |\beta H(j\omega)| = 1\ and$$

$$\angle \beta H(j\omega) = -180\ \ (Barkhausen\ criteria)$$

Unstable and Stable Systems

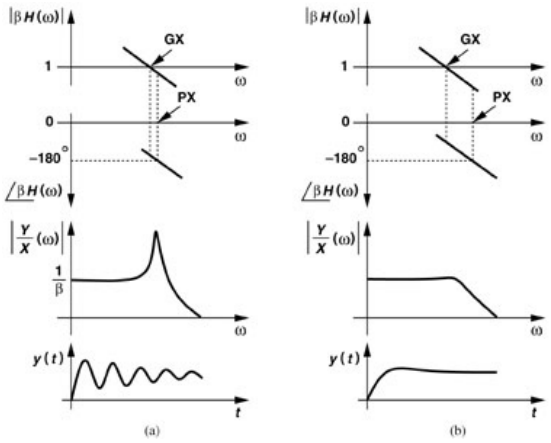


Bode plot for open loop system, poles and zeroes for loop gain

Phase margin

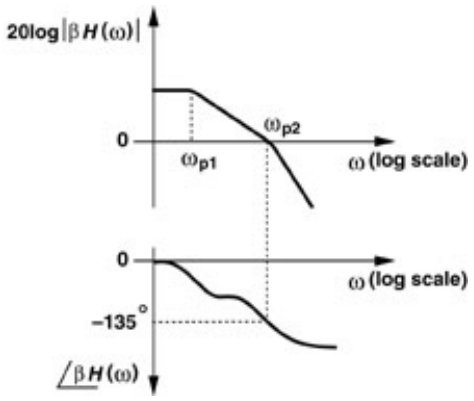
Loop gain

Closed loop gain

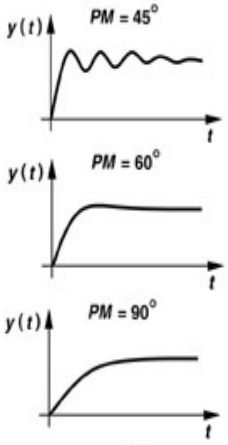


Phase margin and step response

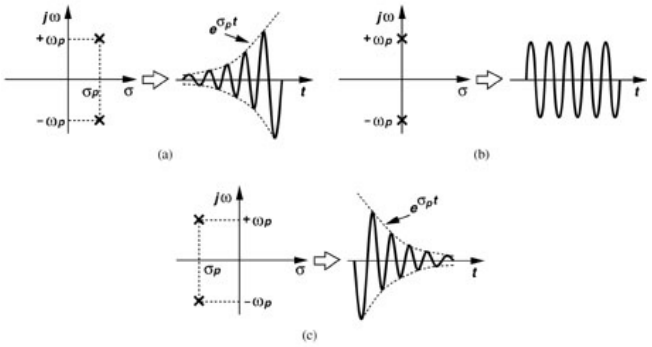
45° phase margin



Step response in time domain



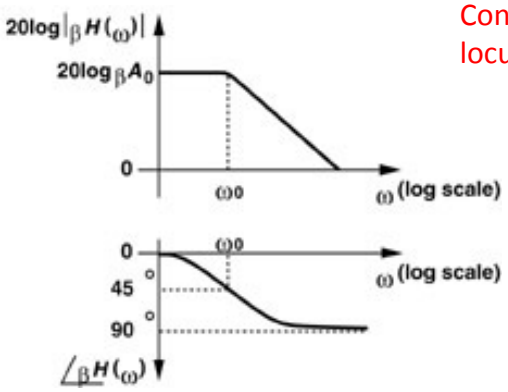
Location of system poles



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

One-pole system

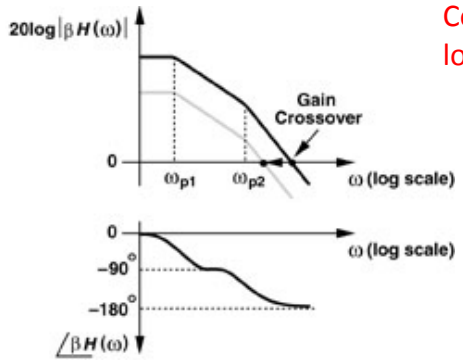
Loop gain



Construct the root locus for this system!

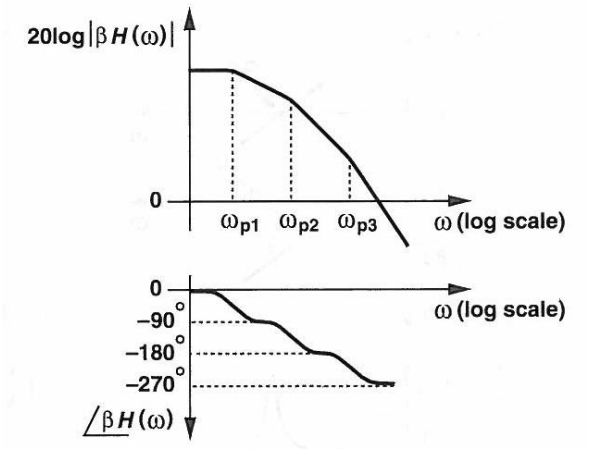
Two-pole system

Loop gain



Construct the root locus for this system!

Three-pole system



Next lecture: Compensation methods, example 10.11