EE539: Analog Integrated Circuit Design

Course summary

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Course goals

Learn to design negative feedback amplifiers on CMOS ICs

- Negative feedback for controlling the output
- Amplifiers, voltage references, voltage regulators, biasing

Course contents-Amplifi ers on ICs

- Components available in CMOS integrated circuit (IC) processes
- Device models-dc small signal, dc large signal, ac small signal, mismatch, noise
- Basic single transistor amplifier stages
- Transistor biasing, compound amplifier stages
- Differential amplifiers
- Fully differential amplifiers and common mode feedback

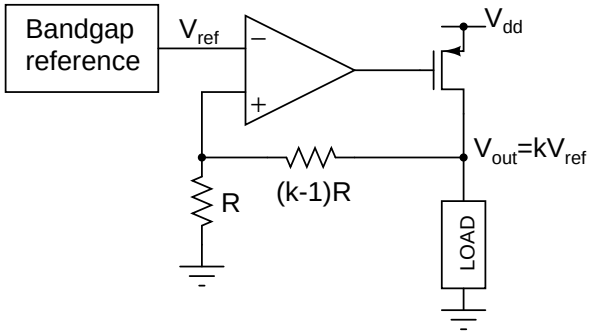
Course contents-Design of opamps

- Single stage opamp
- Folded, telescopic cascode opamps
- Two stage opamp
- Fully differential opamps and common mode feedback
- Applications: Bandgap reference, constant g_m bias generation

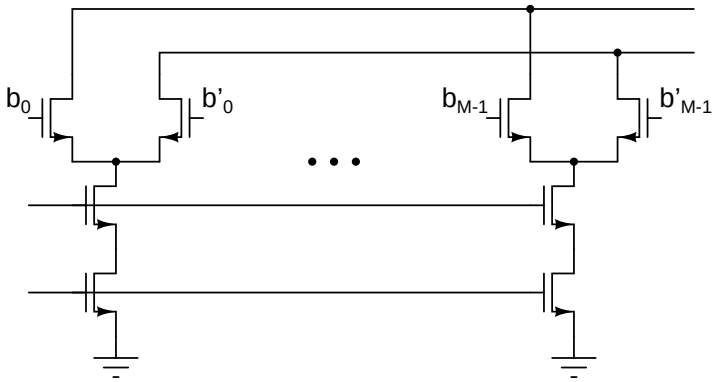
What you should be able to do now

- Analyze negative feedback loops for stability
- Compensate negative feedback loops
- Design transconductors and opamps
- Design appropriate biasing circuits
- Understand other opamp architectures
- Design fully differential circuits with common mode feedback
- Analyze circuit noise and offsets

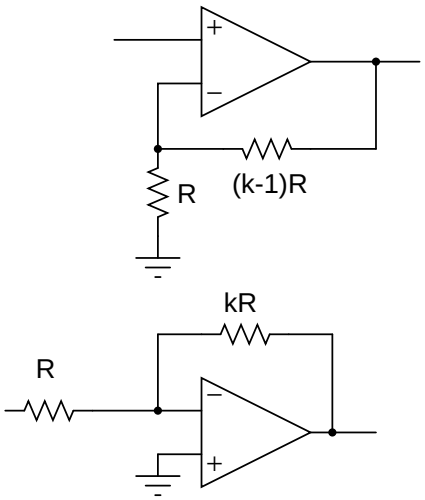
What you should be able to do now



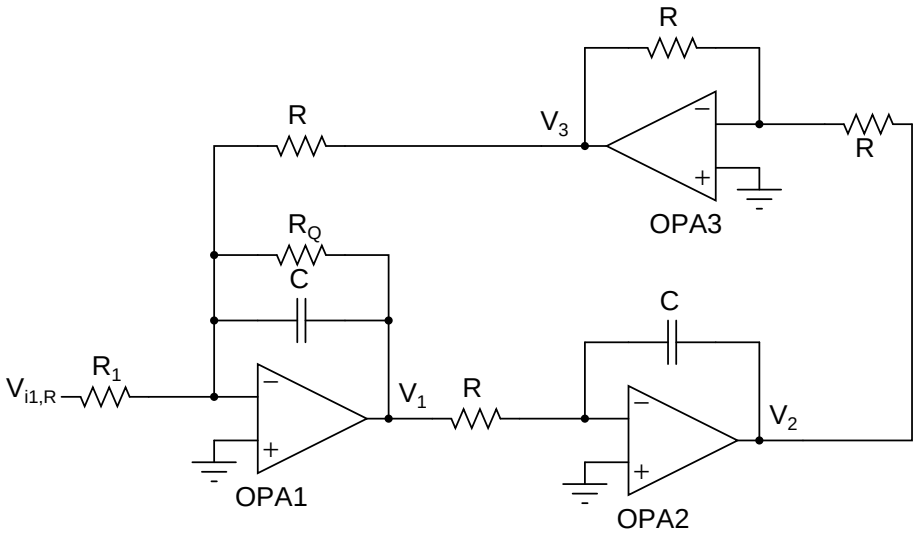
Voltage regulator with reference



Current steering DAC



Feedback amplifiers

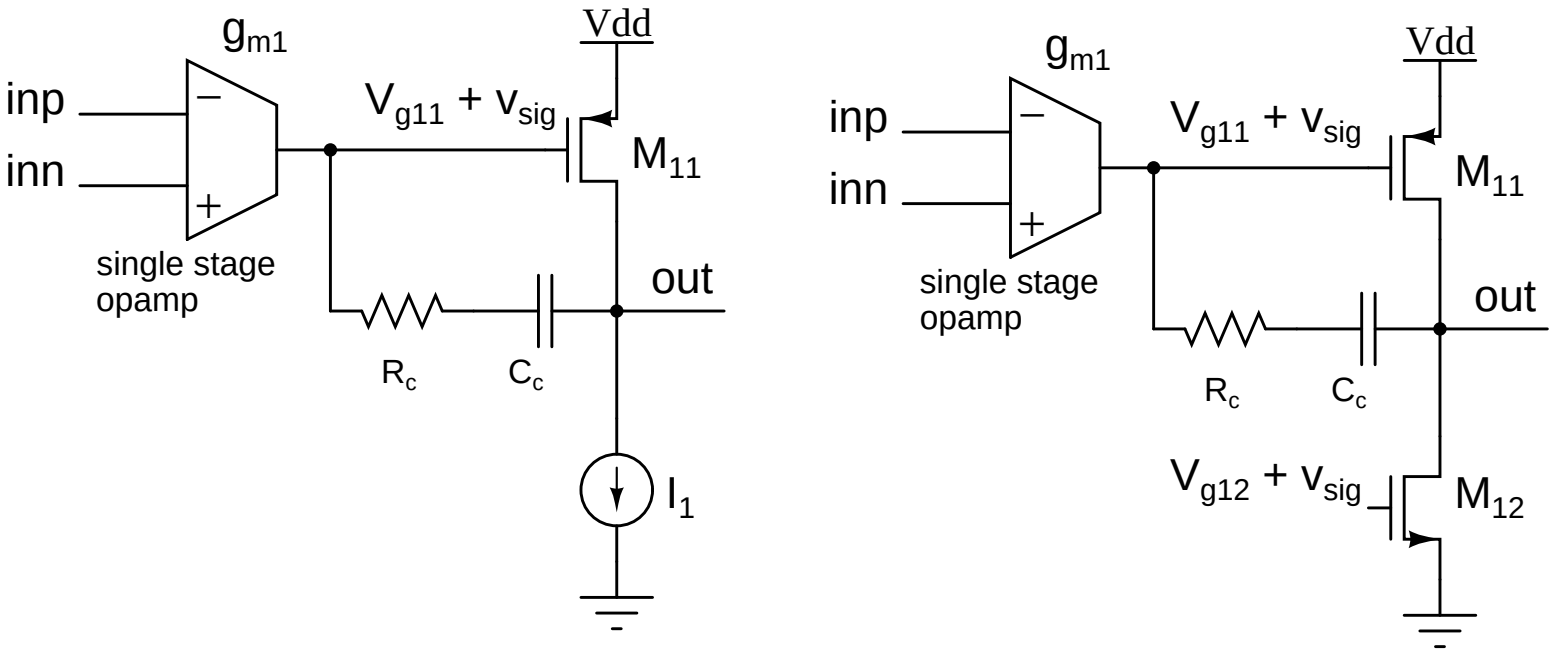


Active RC filter

Other opamp architectures

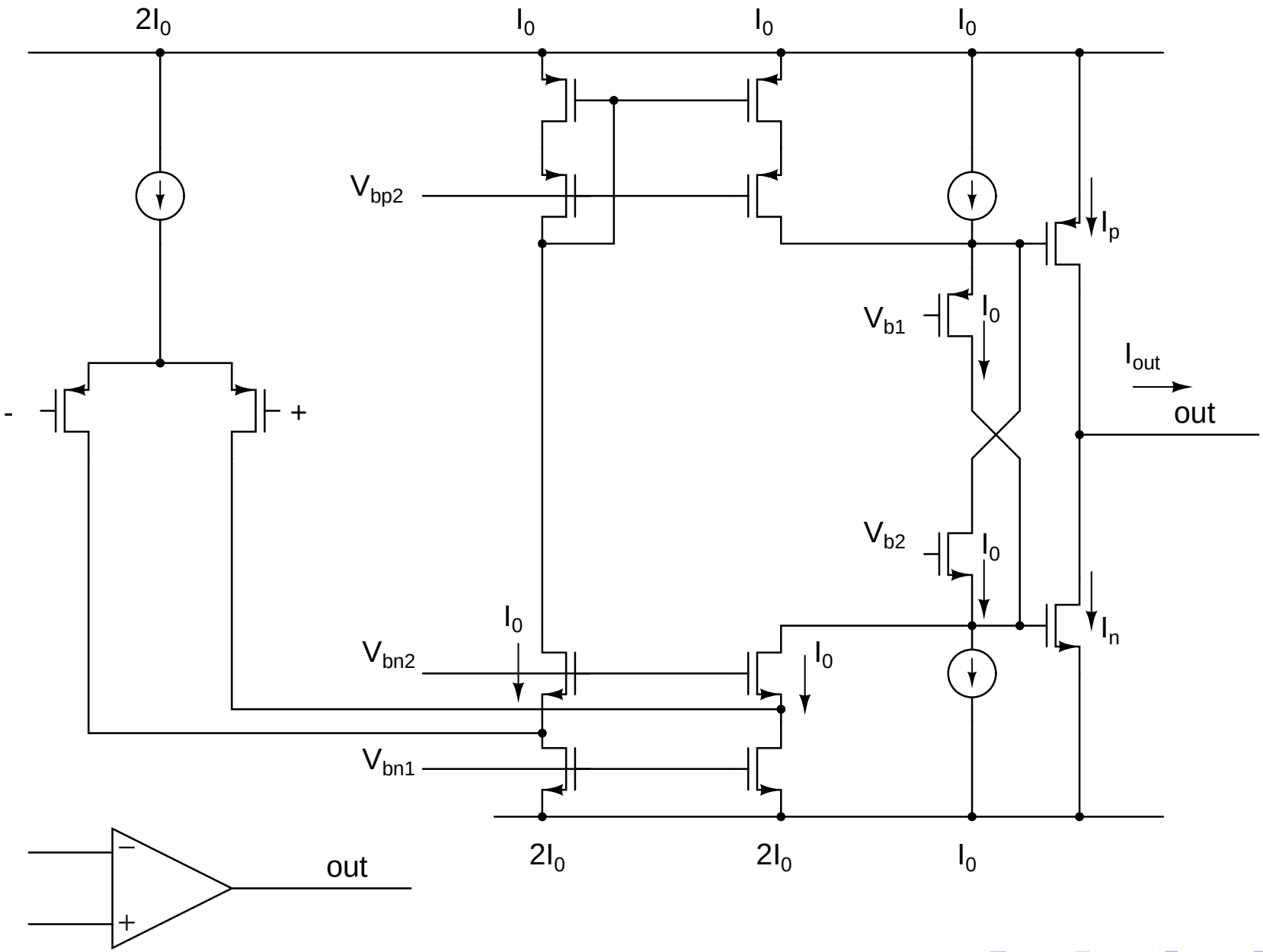
- Class AB output stage
- More than two stages
- Multi path opamp

Class AB opamp



- Large output current drive with a small quiescent current
- Signal coupled to both transistors of the output stage
- Crossover distortion
- Used with heavy loads-headphone driver etc.

Class AB opamp



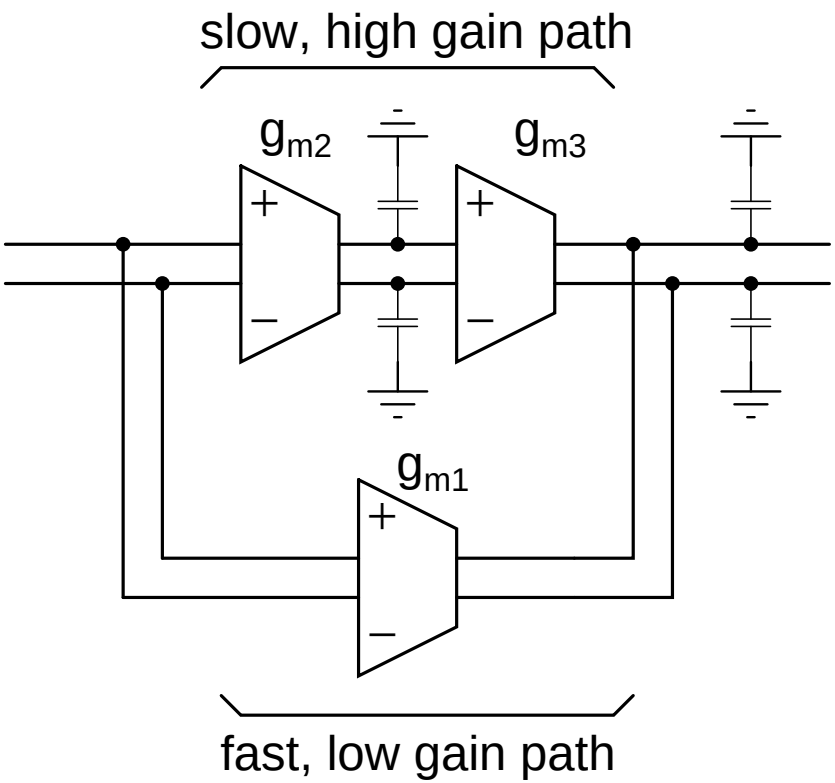
Class AB opamp: References

- D. M. Monticelli, “A quad CMOS single-supply op amp with rail-to-rail output swing,” *IEEE Journal of Solid-State Circuits*, vol. 21, pp. 1026 - 1034, December 1986.
- T. Prabu Sankar, Shanthi Pavan, IITM
  - Switched capacitor “batteries” to couple to the output stage
- S. Rabii and B. A. Wooley, “A 1.8-V digital-audio sigma-delta modulator in 0.8-μm CMOS,” *IEEE Journal of Solid-State Circuits*, vol. 32, pp. 783 - 796, June 1997.

Three stage opamp

- Very high dc gain for high accuracy
- High accuracy DACs (16b)
- Complicated compensation schemes
- Low speed applications
- K. N. Leung and P. Mok, “Analysis of multistage amplifier frequency compensation,” *IEEE TCAS-II*, vol. 48, no. 9, Sep. 2001.

Multi path opamps



- Very high ω_u in a given technology
- Low power dissipation
- Low swing-differential pair output
- Pole zero doublets in close loop transfer functions
  - Not suitable for discrete time applications ???

Multi path opamps

- J. N. Harrison, “Dynamic Range and Bandwidth of Analog CMOS Circuits,” PhD dissertation, Macquarie University, Sydney, 2002.
- T. Laxminidhi, V. Prasadu and S. Pavan, “A Low Power 44-300 MHz Programmable Active-RC Filter in 0.18um CMOS,” *Proceedings of the Custom Integrated Circuits Conference*, San Jose, September 2007.

References

- P. R. Gray and R. G. Meyer, “MOS operational amplifi er design-A tutorial overview,” *IEEE Journal of Solid-State Circuits*, vol. 17, pp. 969 - 982, December 1982.
- D. M. Monticelli, “A quad CMOS single-supply op amp with rail-to-rail output swing,” *IEEE Journal of Solid-State Circuits*, vol. 21, pp. 1026 - 1034, December 1986.
- K. N. Leung and P. Mok, “Analysis of multistage amplifi er frequency compensation,” *IEEE TCAS-II*, vol. 48, no. 9, Sep. 2001.
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