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

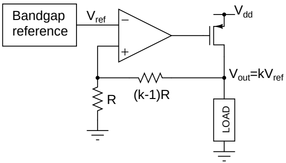
Course contents

- Components available in CMOS integrated circuit (IC) processes
- Noise and offset
- Negative feedback, stability, frequency compensation
- Single stage and two stage opamp
- Fully differential opamp and common mode feedback
- Phase locked loop
- Bandgap reference

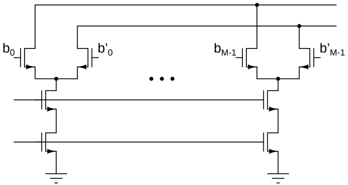
What you should be able to do now

- 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
- Design the basic type-II Phase locked loop
- Understand other phase locked loops, frequency synthesizers, and clock and data recovery circuits

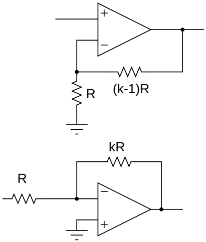
What you should be able to do now



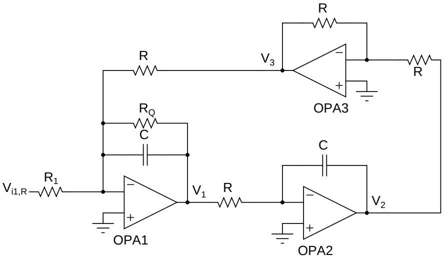
Voltage regulator with reference



Current steering DAC



Feedback amplifiers



Active RC filter

What you should be able to do now

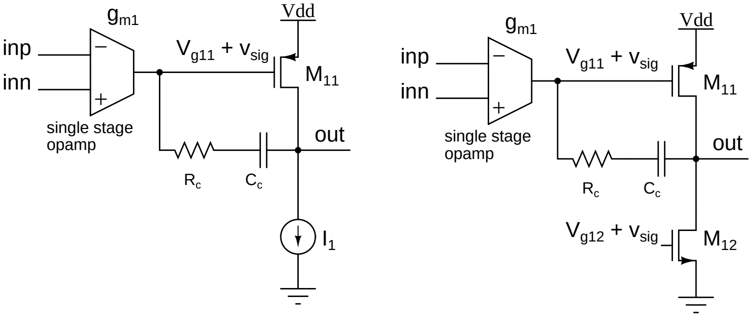
Design

- Multiple options
- Trial and error approach
- Multiple ways of looking at building blocks
- Intuitive thinking/understanding
- Curiosity
- Open mind
- Thoroughness

Other opamp architectures

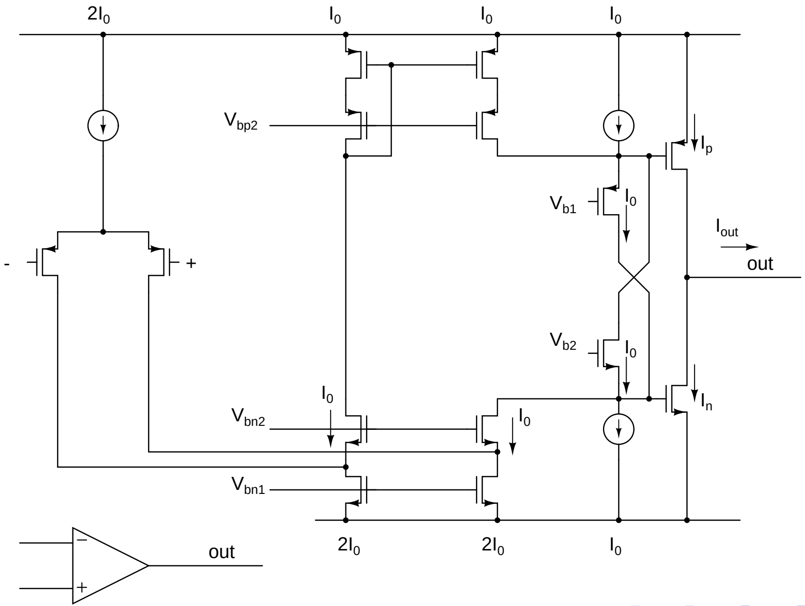
- Cascode opamps—Telescopic and Folded
  - Replace transistors in the single stage opamps with cascodes
- Class AB output stage
- More than two stages
- Feedforward compensated opamps

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



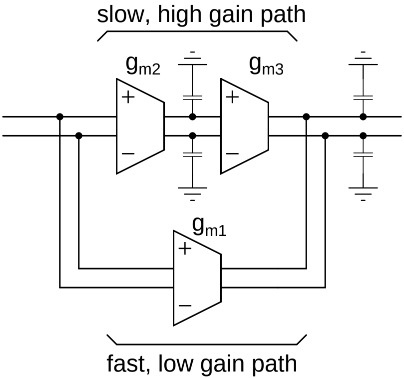
Class AB opamp: References

- 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 amplifier 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 amplifier frequency compensation," *IEEE TCAS-II*, vol. 48, no. 9, Sep. 2001.
- J. N. Harrison, "Dynamic Range and Bandwidth of Analog CMOS Circuits," PhD dissertation, Macquarie University, Sydney, 2002.