--- University of Minnesota ---
Department of Electrical Engineering

Ramesh Harjani EE5505: Analog Integrated Circuit Design Fall 1998

Project

PROJECT PROPOSAL DUE: Monday, October 12
PROJECT REPORT DUE: Friday, December 4

There will be no extentions for the final project reports. Note, this is the last day of class not the last day of the exam week. If you are going to be out of town you can hand in your reports early. Late reports will be not be accepted.

Sequence of steps while working on the project:

a) *Select a project.* Everyone in this class has to design an op amp. You can use the list below or select one of your own. If you are selecting one of your own make sure that you check with me before you start. If you are unsure of what the various projects mean, please, feel free to discuss it with me. And, if possible, please restrict yourself to my office hours.

b) *Choose specs for the project.* For example, if you are going to be working on an low-power operational amplifier, choose the value of the bias current goal that you want to design for. Since performance specifications are correlated, you need to select the complete set of specifications, not just the most important ones. It is important that you take a first stab at these values. Without these goals you will not know what you want to design. To do so you need to look at past examples (papers and books). By October 12 please complete a short report of what you plan to do and the performance specifications that you plan to meet. Also include in your report where/how you think your circuit or tool will be used. Along with this report include a copy of the most important references (pages from books and papers) that you have looked at. This project proposal needs to be typed Handwritten work will not be acceptable. Be a little aggressive about the specifications that you select. It is possible that you may not be able to meet these specifications in the final design. If you do not do so include an explanation in your final report. Performance specifications you want to include are:

- Voltage gain
- Unity gain bandwidth
- Phase margin
- Slew-rate
- Load resistance (if driving off-chip loads)
- Supply voltage (0-5, +2.5 -2.5, 0-3, 0-2, 0-1)
- Output common-mode voltage (+/-)
- Optimiztion criteria (what you want to minimize, i.e., power, area, noise, etc)
- Load capacitance,
- total noise
- Power
- Offset voltage
- Input common-mode voltage(+/-)

Project proposal: A short (2-4 page) proposal describing what you want to do in the project. 5points

c) *Complete your project.* Please, take the time to analyze your circuit. Perform hand calculations and confirm using circuit simulation. It is not sufficient to choose device parameter values out of blue and show through circuit simulation that the circuit meets specifications. If questioned you need to be able to defend your choices. You need to understand how the circuit works.

This is the most important part of the project spend -- time on it. The project is equally, if not more, important than the examinations. Analog circuit design cannot be learned by just writing a test. You have to do it to learn it. The difficulty of the project should be about as much or more than a final examination.

d) *Write your project report.* The final project report needs to be neat and typed. Hand written reports will not be accepted. Please, check your spelling and grammar as well. Even the best project if not presented well will loose its glamour.

Project report: 20 - 30 pages 30points

From sometime in the middle of the quarter the number of homework assignments will decrease so you can concentrate on the project.

Design Ideas

i) Ultra low power operational amplifier with high slew rate capability
Design a op amp that consumes low power under normal conditions but can provide large current into the load when slewing. Hint: this has to be an adaptive circuit.
Static power in the nA region

ii) A fixed gain (maybe 10) instrumentation amplifier. Gain must be very predictable.
Instrumentation amplifier requires high input impedance, large input voltage swing, low noise, etc.

iii) Ultra low noise amplifier. Input referred noise 3µV rms
Lateral bipolar input may be called for.

iv) Ultra low-noise lower frequency CMOS operational amplifier
(Chopper Stabilized/Correlated double sampling)

v) Ultra high frequency CMOS single-stage CMOS amplifier
Think about bandwidths of 300MHZ and gains in the regions of 40dB.

vii) Buffer amplifier to drive off-chip load capacitances (approx. 5000pF)

viii) Folded cascode high bandwidth amplifier

ix) NMOS only operational amplifier

References

Good sources in general:

- IEEE Journal of Solid-State Circuits (particularly December issues)
- IEEE Transactions on Circuits and System
- Electronic Letters

1) Analog MOS Integrated Circuits for signal processing, Roubik Gregorian and Gabor C. Temes, John Wiley & Sons, 1986, Chapter 4

2) CMOS Analog Circuit Design, Phillip E. Allen and Douglas R. Holberg, Holt, Rinehart and Winston, 1986, Chapters 6-9

3) Switched Capacitor Circuits, P.E. Allen and E. Sanchez-Sinencio, Van Nostrand Rienhold, 1984

4) An Integrated NMOS Operational Amplifier with Internal Compensation, IEEE Journal of Solid-State Circuits, December 1976

5) State-of-the-Art and Future Prospects of Analogue Signal Processing -A Tutorial, Gabor C. Temes, Lawrence E. Larson and Kenneth W. Martin, IEEE International Symposium on Circuits and Systems, 1988

6) Principles of Operation and Analysis of Switched-Capacitor Circuits, Yannis Tsividis, Proceedings of IEEE, vol. 71, pp 926-940, August 1983

7) MOS Switched-Capacitor Filters, Robert W. Brodersen, Paul R. Gray and David A. Hodges, Proceedings of the IEEE, vol. 67, pp 61-75, January 1979

8) Technological Design Considerations for Monolithic MOS Switched-Capacitor Filtering Systems, David J. Allstot and William C. Black, Proceedings of IEEE, vol. 71, August 1983

9) Analysis and Design of Analog Integrated Circuits, P.R. Gray and R.G. Meyer, John Wiley & Sons, 1993

10) A CMOS Operational Amplifier with Low Impedance Drive Capability, D.G. Meading, IEEE Journal of Solid-State Circuits, December 1983

11) An Improved Frequency Compensation Technique for CMOS Operational Amplifiers, IEEE Journal of Solid-State Circuits, December 1983

12) Operational Amplifiers - Design and Applications, J.G. Graeme, G.E. Toby and L.P. Huelsman, McGraw Hill, 1974

13) Measurement of Operational Amplifier Characteristics in the Frequency Domain, W.M.C Sansen, M. Steyaert, and P.J.V. Vandeloo, IEEE Transactions on Instrumentation and Measurement, March 1985

14) Class AB CMOS Amplifier for Micropower SC Filters, Electronics Letters, June 25 1981, pp 433-435