Approval: 8th Senate Meeting

Course name: CMOS Analog IC Design

Course number: EE512

Credit: 3-0-2-4

Prerequisite: Network theory (EE203), Signals and System (IC260), Control Theory (EE301) and the Instructor's consent.

Intended for: 3rd and 4th Year UG/PG

Elective or Core: Elective

Semester: Even/Odd

Course Preamble: This course builds the basic concepts and the design of advanced CMOS analog Integrated Circuit. The course is intended to teach undergraduate and graduate students. This course focuses on the concepts of MOSFETs and design of amplifiers including non-linear effects. The course will give practical aspect of CMOS analog IC design. As a part of this course, the students will use industry standard softwares and tools such as Cadence's Virtuoso schematic, Spectre simulator and Mentor Graphics' Eldo and Calibre for post layout simulations along with the parasitic extractions. The design problems given in the form of assignments will be designed and simulated in a standard 0.13 μm CMOS technology by students. The study will cover design issues on the PVT variations and statistical mismatches in temperature and process (using MonteCarlo method). In summary, the course is designed with considering the need of VLSI design industry. To get better understanding of the course, 2 hours of laboratory session per week will be arranged. In laboratory, there will be experiments, considering all the modules of the course.

Course outline: The course aims to teach basic concepts along with advanced design techniques for CMOS amplifiers. The objective of the course is to design and implement the product level opamps and buffers for VLSI applications.

Course Modules:
MOS device models and short channel effects [4 Lectures]

MOSFET level 1 and level 2 models, threshold voltage model, capacitance model, mobility model, MOSFET basics, small-signal model derivation for a single transistor amplifier
Process, voltage, temperature (PVT) dependency and analog layout design essential onsiderations

Single stage amplifiers: **[4 Lectures]**

Basic concept, Common source stage: with resistive load, with diode connected load, with current-source load, with triode load, with source degeneration
Source follower (common-drain) and common gate with various loads
CMOS Differential amplifiers: [4 Lectures]

Single ended differential operation, basic differential pair (qualitative and quantitative analysis), common mode response, differential pair with MOS loads and Gilbert cell multiplier

Concept of matching transistors for analog layout, analog layout techniques for differential amplifier

CMOS Current mirrors: [4 Lectures]

Scheme and implementation: basic current mirrors, cascode current mirrors and active current mirrors with large and small signal analysis
Understanding of common-mode properties
Analog layout making techniques for current mirrors

CMOS amplifier Frequency response: [4 Lectures]

Miller effect, common source (CS), common gate (CG), common drain (CD) stages and cascode stage
Analog layout techniques for MIM, MOM and fringe capacitor

Noise analysis of the CMOS amplifier circuits: [4 Lectures]

Types of noise, significance of flicker and thermal.
Analysis and representation of noise in single stage amplifiers: CG, CS, CD (source follower) and cascode stage and noise in differential pairs.

Feedback [4 Lectures]

Feedback topologies (voltage-voltage, current-voltage, voltage-current, current-voltage) and the noise and the loading effect analysis.

Design of the CMOS operational amplifiers: [9 Lectures]

One-stage opamps and two stage opamps,
Gain boosting techniques, folded cascode, telescopic amplifier and common mode feedback (CMFB) amplifier
Three stage opamp architectures, opamp specifications analysis,
Design of high speed and high gain amplifiers

Stability and frequency compensation [4 Lectures]

Specification analysis, multi-pole system, three stage opamp, phase margin
Frequency compensation, pole-zero doublet analysis

Analog layout techniques [1 Lectures]

Design rule check (DRC), layout versus schematic (LVS) and antenna effects
Design of pad-ring and gds file generation

Text book:

1. "Design of Analog CMOS Integrated Circuits" by Behzad Razavi, McGraw Hill Education (1 September 2000)

Reference books:

1. "CMOS Analog Circuit Design" by Phillip Allen and Douglas R. Holberg, OUP USA; Third Edition edition (1 September 2011).
2. "Operation and Modeling of the MOS Transistor" by Yannis Tsividis, Oxford University Press; 2 edition, June 26, 2003
3. "Microelectronic Circuits-Theory & Applications" by A.S. Sedra and K.C. Smith, Adapted by A.N. Chandorkar, 6^{th} Edition, Oxford, 2013.