University of Tehran
School of Electrical and Computer Engineering

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<tr><td>Course:</td><td>8101089 – Electronics 3</td></tr>
<tr><td>Course type:</td><td>
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<tr><td></td><td colspan="6">EE*</td><td colspan="3">CE*</td><td rowspan="4">Credit: 3</td></tr>
<tr><td></td><td>Com</td><td>E</td><td>P</td><td>B</td><td>Con</td><td>D</td><td>SW</td><td>HW</td><td>IT</td></tr>
<tr><td>Required</td><td>☒</td><td>☒</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
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<tr><td>Level:</td><td>Undergraduate ■
Graduate ☐</td></tr>
<tr><td>Co-requisite(s):</td><td>Linear Control Systems (8101224)</td></tr>
<tr><td>Prerequisite(s):</td><td>Electronics 2 (8101088)</td></tr>
<tr><td>Prerequisite by topic:</td><td>• Introduction to Basic CMOS and BJT Transistors and their Models and Physics
• Different Small-signal Model types for CMOS and BJT Transistors
• Single Stage CMOS and BJT Amplifier Design
• Current Mirrors
• Class AB Amplifier Design
• Differential Pairs
• Introduction to Operational Amplifier Usage and applications
• Feedback in Amplifiers
• Output Stage Amplifiers</td></tr>
<tr><td>Textbook(s):</td><td>[1] Design of Analog CMOS Integrated Circuit, Behzad Razavi, McGraw-Hill 2001
[2] Analysis and design of Analog Integrated Circuits, Gray–Hurst-Lewis-Mayer, Forth Edition John Wiley & SONS INC. 2004
[3] Design of Analog Integrated circuit & systems, Kenneth R. Laker, Willy M.C. Sansen, McGraw-Hill 1994
[4] Microelectronic Circuit, Adel S. Sedra, Kenneth C. Smith, Saunders College publishing 1991
[5] Analog Integrated Circuit Design, David A. Johns, Ken Martin, John Wiley & Sons Inc.1997</td></tr>
<tr><td>Coordinator:</td><td>Dr. Omid Shoaei, Professor, School of ECE</td></tr>
<tr><td>Goals:</td><td>• Basic CMOS and BJT amplifier design topologies are reviewed and Basic Differential Pair Circuits with more depth
• The methods for analyzing Frequency response of the single-stage and multi-stage amplifiers are introduced as a major part of the course
• The notion and criteria of Stability in amplifier is introduced and analogies from linear control theory are given</td></tr>
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The methods to improve the amplifier stability in feedback are introduced and a complete design solution for a two-stage operational amplifiers is given.
Time permitting stability compensation methods for cascade amplifiers and those with three- and higher number of stages are given

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<tr><td>Outcome:</td><td>Upon successful completion of the course, students will be able

Analyze the frequency response of basic and multi-stage amplifiers
Understand in more details the behavior of differential circuits and common-mode response and also the common-mode feedback
Analyze the stability of amplifiers from both small-signal frequency response view point as well as large-signal step response linear analysis
Learn different methods to improve the stability of amplifiers in feedback

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<tr><td>Topics:</td><td>
1) MOS Transistor Models and physics

MOSFET and Junction FET
MOS capacitor
MOS threshold
MOS regions (linear & saturation) characteristic
Small-Signal Model
Examples of small-signal Analysis
Transconductance Amp
Diode
Source Follower
Capacitance
Higher order models

2) Bipolar Transistor Models

Hybrid-small-signal model (for BJT)
model elements
Common-Emitter (current drive, voltage drive)
Common-Collector
Common - Base
Ohmic Resistance
Lateral PNP transistors
Other Components
Base diffusion resistor
Other resistor
Capacitor
Inductor

3) Single-Stage Amplifiers

Basic Concepts
Common-Source Stage
Common-Source Stage with Resistive Load
CS Stage with Diode-Connected Load
CS Stage with Current-Source Load
CS Stage with Triode Load
CS Stage with Source Degeneration
Source follower
Common-Gate Stage

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- *Cascode stage*
  - *Folded Cascode*
- *Choice of Device Models*

4) ***Differential Amplifiers***
- Single-Ended and Differential operation
- Basic Differential Pair
  - Qualitative Analysis
  - Quantitative Analysis
- Common mode Response
- Differential Pair with MOS Loads

5) ***Frequency Response of Integrated circuits***

- Single-Stage Amplifier frequency response
  - Differential Amp frequency response
  - Common-Mode (CM) gain in diff pair
  - Emitter-follower freq response
  - Common-Base freq response
- multistage Amp freq response
  - Dominant Pole Approximation
  - Zero-value Time constant Analysis
  - Common-Emitter cascade freq response
  - Cascode freq response

6) ***Elementary Transistor stages***
- MOS single Transistor Amplifying stages
  - Biasing ,Gain ,Bandwidth , high frequency performance ,
  - Unity- Gain freq & GBW product
- Source & Emitter Followers
  - DC level shift ,high freq Gain ,Output Impedance
- Cascode Transistors
  - MOS cascode (Low freq Analysis ,high freq performance).
  - Bipolar cascode
- Cascode stages
  - BW of cascode w/ low and w/Active load ,High voltage cascode,
  - cascode w/Bipolar ,Feedforward in cascode Amp

- Differential Stage
  - MOS differential stages (DC characteristic , small-signal
  - behavior ,low freq analysis ,GBW product, Slew-rate)
- Current mirrors
  - Simple MOS current Mirror
- Other current mirror
  - Bipolar current mirror
  - Gain factor mismatch
  - Body factor mismatch
  - Offset voltage
  - Mismatch effects on Current mirror
  - Differential stage w/ Active load
  - CMRR
  - Design for low offset and drift

	○ Power Supply Rejection Ratio (PSRR) ▪ Design options ○ Design for optimum GBW or SR ○ Compensation of the Positive Zero **7) *Frequency Response stability of feedback Amplifiers*** ▪ The Stability Problem ***8) Operational Amplifier Design*** ▪ Design of a simple CMOS OTA ○ Gain ○ GBW and Phase Margin ▪ Design plan : optimization for Maximum GBW ▪ The Miller CMOS OTA ○ Operation ○ Gain ○ GBW and ○ Design plan : Determine Compensation Cap Cc Determine size and current ▪ Full set of characteristic of Miller OTA ○ CM input vs. supply ○ Output voltage range vs. Supply ○ Max output current (sink and source) ○ AC analysis :low freq. ○ GBW vs.. ○ Slew-rate vs. load cap ○ Output voltage range vs. Frequency ○ Settling time ○ Output Impedance ○ temperature effects ▪ Matching characteristics ○ transistor Mismatch model ○ Threshold voltage Mismatch
Computer usage:	• For Computer Assignments & Design Project
Assignments:	• 10 take-home assignments including: • 3 Computer Assignments • 4 quizzes
Projects:	A Computer Circuit Design Project with HSPICE
Grading:	Assignments: 10 % Projects: 5 % Quizzes: 5 % Midterm exams: 30 % Final exam: 50 %
Further readings:	[1]
Prepared by:	Dr. Omid Shoaei, Professor, School of ECE
Date:	September 2017

*EE: Electrical Engineering	CE: Computer Engineering

Com	Communications	SW	Software
E	Electronics	HW	Hardware
P	Power	IT	Information Technology
B	Bioelectronics		
Con	Control		
D	Digital System		