GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Branch: Electronics & Communication (VLSI System Design)

Course / Subject Code : ME01000381

Course / Subject Name : Analog CMOS Circuit Design

w. e. f. Academic Year:	2024-25
Semester:	1st Semester
Category of the Course:	PEC

Prerequisite:	Basic Electronic Circuit Design Concepts and CMOS based circuits.
Rationale:	The students need to learn basic concepts of CMOS based analog circuits and system which leads to design of complex analog system. The students need to know basic of analog circuits. The students will learn the design of various basic analog building blocks such as single stage amplifiers, differential amplifier, op-amp, etc. This is the first course by which students get exposure to CMOS based analog circuit design world.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
01	Design and analyze different configurations of single stage amplifiers and current mirror building blocks.	C
02	Understand basic principle, operation and applications of differential amplifier, to design and perform parametric analysis of the differential amplifier.	U
03	Understand limitations of single stage amplifiers and design multistage amplifiers such as twostage op-amp.	U
04	Analyze two-stage op-amp in terms of various important parameters such as CMRR, ICMR, SR, and PSRR.	N
05	Study and analyze frequency response and noise performance of multistage amplifiers.	N

**Revised Bloom's Taxonomy (RBT)*

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA / CA (M)	PA/CA (I)	ESE (V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Introduction to CMOS Analog Circuit Design** : Introduction to Analog Design, Basic MOS Device Physics – General Consideration, MOS I/V Characteristics, Second-Order Effects, MOS Device Models	4	10
2.	**Single-Stage Amplifiers** : Basic Concepts, Common-Source Stage, Source Follower, Common Gate Stage, Cascode Stage - Folded Cascode	8	20
3.	**Passive and Active Current Mirrors** : Basic Current Mirrors, Cascode Current Mirrors, Active Current Mirrors	5	10
4.	**Differential Amplifiers**: Single-Ended and Differential Operation, Basic Differential Pair, Common-Mode Response, Differential Pair with MOS Loads, Gilbert Cell.	8	15
5.	**Frequency Response of Amplifiers** : General Considerations, Common-Source Stage, Source Followers, Common-Gate Stage, Cascode Stage, Differential Pair	4	10
6.	**Operational Amplifiers**: General Considerations, One-stage Op Amps, Two-Stage Op Amps, Gain Boosting, Comparison, Common-Mode Feedback, Input Range Limitations, Slew Rate, Power Supply Rejection, Noise in Op Amps.	9	20
7.	**Stability and Frequency Compensation** : Introduction, Multipole Systems, Phase Margin, Frequency Compensation, Compensation of Two-Stage Op amp, Other Compensation Techniques.	7	15
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
10	**20**	**20**	**30**	**10**	**10**

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. Design of Analog CMOS Integrated Circuits, Behzad Razavi, TMH
2. CMOS Analog circuit design, P. E. Allen and D.R. Holberg
3. CMOS Circuit Design, Layout, and Simulation, R. Jacob Baker, Wiley, 2nd Edition

(b) Open source software and website:

1. Ng-Spice/Multisim
2. https://nptel.ac.in/
3. http://www.ee.iitm.ac.in/vlsi/courses/ee5320_2021/start
   https://nptel.ac.in/courses/117/106/117106030/

Suggested Course Practical List: (30 Hours)

1. Measure and analyze the I-V characteristics of MOS transistors (nMOS and pMOS) for different biasing conditions.

2. Measure and analyze the impact of various parameters such as Vth, λ, γ on the input and output characteristics of MOS transistors (nMOS and pMOS).

3. Study the various SPICE model levels (Level-1, Level-2, BSIM3 or BSIM4) for MOS transistors (nMOS and pMOS).

4. Extract Vth of nMOS/pMOS transistors using gm v/s VGS plot at VDS of appropriate voltage. Perform the experiment for short channel and long channel nMOS/pMOS transistors (use different technology models) and tabulate the results and comment on it.

5. Investigate the transfer characteristics of a CMOS inverter by varying the input voltage and observing the output response. Measure parameters such as voltage transfer characteristics, noise margin, and power dissipation.

6. Design and implement the resistive load common source amplifier and analyze its voltage gain, frequency response, and input/output characteristics.

7. Design and implement the diode connected load common source amplifier and analyze its voltage gain, frequency response, and input/output characteristics.

8. Design and implement the source degenerated common source amplifier and analyze its voltage gain, frequency response, and input/output characteristics.

9. Design and implement the common gate amplifier and analyze its voltage gain, frequency response, and input/output characteristics.

10. Design and implement the source follower and analyze its voltage gain, frequency response, and input/output characteristics.

11. Design and implement basic cascade amplifier and analyze its voltage gain, frequency response, and input/output characteristics. Compare the results with common source amplifier.

12. Design and implement a basic current mirror circuit. Evaluate its performance in terms of output current accuracy and stability.

13. Design and implement a cascade current mirror circuit. Evaluate its performance and compare the results with basic current mirror circuit.

14. Design and simulate a differential amplifier using MOS transistors. Analyze its common-mode rejection ratio (CMRR), differential gain, and linearity.

15. Design and simulate a two-stage operational amplifier circuit using MOS transistors. Characterize its gain, bandwidth, slew rate, and stability. To implement and analyze the basic differential pair circuit.

16. Study and compare the single stage differential amplifier and two-stage operational amplifier circuits in terms of their frequency responses using the frequency dependent characteristics of gain, bandwidth, and phase.

17. Seminar/Mini Project

Open Ended Problems:

1. Design a common source amplifier with typical value of gain.
2. Design a CS stage with source degeneration with typical value of Gm.
3. Design a common gate amplifier with typical value of gain.
4. Implement a folded Cascode circuits using Spice.
5. Find voltage gain of differential circuits.
6. Implement Gilbert cell with Spice.
7. Design Cascode current mirror for a typical values of current.
8. Derive large signal and small signal analysis for Active current Mirrors.
9. Find input impedance for Source follower at high frequency.

* * * * * * *