GUJARAT TECHNOLOGICAL UNIVERSITY

ELECTRONICS & COMMUNICATION (SIGNAL PROCESSING AND VLSI TECHNOLOGY) (26)

PHYSICS OF MOS TRANSISTOR

SUBJECT CODE: 2712605

SEMESTER: I

Type of course: Advanced Semiconductor Active Device Modeling

Prerequisite: Fundamental knowledge of semiconductor and devices, and mathematics

Rationale: Students of ME in VLSI must possess a good understanding of concepts of modeling of MOSFET. Students also must learn about various short channel effects and its modeling. This is one of the foundation courses which are required for designing state-of-art MOSFET based circuits for applications demanding low-power, low-voltage, and high speed

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks		Practical Marks				
				ESE (E)	PA (M)	PA (V)		PA (I)		
						ESE	OEP	PA	RP	
4	2#	2	6	70	30	20	10	10	10	150

Content:

Sr. No.	Topics	Teaching Hrs.	Module Weightage
1	**Semiconductors, Junctions, and MOSFET Overview:** Semiconductors, Conduction, Contact Potentials, *pn* junction, Overview of MOS Transistor	5	
2	**Two-Terminal MOS Structure:** Introduction, Flat-band voltage, Potential and Charge balance, Effect of Gate-Substrate Voltage on Surface Condition, Regions of Inversion and Analysis, Small-Signal Capacitances	8	
3	**Three-Terminal MOS Structure:** Introduction, Contacting the Inversion layer, Body effect, Regions of Inversion and Mathematical Analysis, Study of MOS Structure from "VCB" Control Point of View	6	
4	**Four-Terminal MOS Structure:** Transistor Regions of Operation, General Charge Sheet Models, Strong Inversion, Weak Inversion, Moderate Inversion, Interpolation Models, Source Referenced versus Body Referenced Modeling, Effective Mobility, Temperature Effects, Breakdown, p-channel MOS Transistor, Enhancement-Mode and Depletion-Mode Transistors, Model Parameter Values, Model Accuracy, Model Comparison	10	
5	**Small-Dimension Effects:** Introduction, Channel Length Modulation, Barrier Lowering, Two-Dimensional Charge Sharing, Threshold Voltage, Punch-through, Carrier Velocity Saturation, Hot Carrier Effects, Scaling, Effects of Surface and Drain Series Resistances, Effects due to Thin Oxides and High Doping	8	
6	**The MOS Transistor in Dynamic Operation – Large-signal**	8	

	Modeling: Introduction, Quasi-static Operation, Terminal Currents in Quasi-static Operation, Evaluation of Charges in Quasi-static Operation, Transit Time under DC Conditions, Limitations of the Quasi-static Modeling, Non-Quasi-Static Modeling		
7	**MOSFET Modeling for Circuit Simulation:** Introduction, Types of Models, Combining Several Effects into One Physical Model, Parameter Extraction, Accuracy, Properties of Good Models, General Considerations, Benchmark Tests, Nontechnical Considerations	7	

Reference Books:

1. Operation and Modeling of The MOS Transistor, Y. Tsividis
2. S. M. Sze, Physics of Semiconductor Devices, (2e), Wiley Eastern
3. N. D. Arora, MOSFET Models for VLSI Circuit Simulation, Springer-Verlag

Course Outcome:

Students will get sound knowledge in following topics which are required for design of advanced MOSFET circuit**s.**

1. Semiconductor physics.
2. MOS capacitor modeling and effects of frequency on C-V characteristic.
3. MOSFET modeling techniques.
4. Short-channel effects and its modeling.
5. Need of large signal MOSFET modeling.
6. MOSFET parameter measurements.
7. Benchmark tests for MOSFET models

List of Experiments:

1. To obtain $I_D - V_{GS}$ characteristic of n-channel and p-channel MOSFET for different values of V_{DS} and V_{BS}. (180 nm technology)
2. To obtain $I_D - V_{DS}$ characteristic of n-channel and p-channel MOSFET for different values of V_{GS} and V_{BS}. (180 nm technology)
3. To obtain C – V characteristic of p-type substrate MOS capacitor. (180 nm technology)
4. To obtain V_{Tn} as a function of V_{BS} for n-channel MOSFET device and calculate body-bias parameter. (180 nm technology)
5. To obtain V_{Tn} as a function of V_{DS} for n-channel MOSFET device and calculate DIBL parameter. (180 nm technology)
6. To obtain leakage current as a function of V_{DS} for n-channel MOSFET device and calculate subthreshold (SS) parameter. (180 nm technology)
7. To observe CLM effect from $I_D - V_{DS}$ characteristic of n-channel MOSFET device and calculate output resistance. (180 nm technology)
8. To obtain $g_m - V_{GS}$ characteristic of n-channel and p-channel MOSFET for different values of V_{DS} and V_{BS}. Calculate threshold voltage from $g_m - V_{GS}$ characteristic. (180 nm technology)
9. To obtain following parameters for two different technologies (180 nm and 90 nm) and compare them.

a) DIBL
b) SS
c) Output resistance

10. To observe the effect of leakage current, simulate CMOS inverter circuit in 180 nm and 90 nm technology and obtain leakage power dissipation
11. To measure I_D –V_{GS} and I_D - V_{DS} characteristic for n-channel/p-channel MOSFET device. Obtain following parameters:

a) Body-bias parameter
b) DIBL
c) SS
d) Output resistance

Open Ended Problems:

1. Write a 'c' program to obtain g_m - V_{GS} from I_D –V_{GS} characteristic for n-channel/p-channel MOSFET device.
2. Write a 'c' program to obtain g_{ds} – V_{DS} from I_D - V_{DS} characteristic for n-channel/p-channel MOSFET device.
3. Write a 'c' program to obtain threshold voltage from I_D - V_{GS} characteristic for n-channel/p-channel MOSFET device.
4. Write a 'c' program to obtain leakage current information from I_D – V_{GS} characteristic for n-channel/p-channel MOSFET device.
5. Write a 'c' program to obtain output resistance from I_D – V_{DS} characteristic for n-channel/p-channel MOSFET device.
6. Write a 'c' program to obtain body-bias parameter from I_D - V_{GS} characteristic for n-channel/p-channel MOSFET device.
   Write a 'c' program to obtain DIBL parameter from I_D - V_{GS} characteristic for n-channel/p-channel MOSFET device.

Major Equipments :

i. Function Generator
ii. Oscilloscope
iii. Digital Multi-meter
iv. DC Power Supply (0-30 V)

List of Open Source Software/ Learning website:

Multisim, PSPice, NGspice (**Open Source Software)**