Amrita Vishwa Vidyapeetham

Amrita School of Engineering, Coimbatore

Department of Electronics and Communication Engineering

1. **Course Code**: 25VL601

2. **Course Title:** Semiconductor Device Modelling

3. **Course Type (Core Course/Elective**): Core

4. **Course Mentor:** Dr. Abhishek Raj

5. **Course Instructor(s):** Dr. Abhishek Raj

6. **Academic year:** 2025 – 2026 Odd

7. Course Objectives and Course Summary:

Learning Objectives:

- Understand semiconductor fundamentals, pn junctions, and MOS structure behavior.
- Analyze two- and three-terminal MOS devices, focusing on inversion and capacitance.
- Model four-terminal MOS transistors across operating regions with practical effects.
- Study short-channel effects, develop large-signal and non-quasi-static models, and gain an overview of modern semiconductor devices.

Course Summary:

Students will understand MOS transistor operation, analyze scaling effects, apply modeling techniques for circuit simulation, and optimize VLSI designs.

8. Course Outcomes (COs):

CO1: explain the physical behavior of intrinsic and extrinsic semiconductors, pn junctions, and MOS structures under various biasing conditions.
CO2: analyze the characteristics of two- and three-terminal MOS devices and interpret the effects of gate voltage on device behavior.
CO3: model four-terminal MOS transistors considering different regions of operation, mobility variations, and temperature effects.
CO4: evaluate short-channel effects and develop models for scaled MOS devices, with an overview of advanced structures including SOI, Double Gate, FinFET, and GAA-FETs.

9. Mapping/Alignment of COs with Program Outcomes (POs):

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO6
CO 1	-	-	-	3	-	-
CO 2	-	-	-	3	2	-
CO 3	-	-	-	3	3	2
CO 4	-	-	-	3	3	2

10. Comments from previous course offering: NA

11. Reflection by the current course instructor(s): Mathematical modelling of MOS transistor to be focused.

12. Class Schedule/Lesson Plan/Weekly plan

Topics	Lecture(s)	Specific Outcome	Teaching Strategies & Suggested Activities	Teaching Reading Materials	Assessment Technique	Alignment to COs
Basics of Semiconductor – Intrinsic and Extrinsic Semiconductors, Equilibrium in absence and presence of Electric Field	1-2	Understand carrier concentrations in intrinsic/extrinsic semiconductors and explain equilibrium behavior under applied electric fields.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 1 (Text book 1)	Midterm Exam, End sem Exam	CO1
Non-Equilibrium and Quasi-Fermi Levels, Charge Density, Electric Field, Potential, Poisson's Equation	3 - 6	Analyze non-equilibrium carrier distributions using quasi-Fermi levels and solve Poisson's equation to determine electric potential profiles.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 1 (Text book 1)	Midterm Exam, End sem Exam	CO1
Transit Time, Drift and Diffusion current, Contact Potentials, The pn Junction	7-9	Calculate carrier transport parameters and describe the I-V characteristics and built-in potential of a pn junction.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 1 (Text book 1)	Midterm Exam, End Sem Exam	CO1
Overview of the MOS Transistor – Structure, Operation and Characteristics of MOS Transistor.	10-11	Illustrate MOS transistor structure and explain its basic operation in cutoff, linear, and saturation regions.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 1 (Text book 1)	Quiz, Midterm Exam, End Sem Exam	CO1
Quiz-I						

The Two-Terminal MOS Structures – Flatband Voltage, Potential Balance and Charge Balance, Effect of Gate-Body Voltage on Surface Condition	12-13	Evaluate surface conditions for two-terminal MOS structures under varying gate voltages.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 2 (Text book 1)	Midterm Exam, End Sem Exam	CO1, CO3
Accumulation and Depletion, Inversion, Small-Signal Capacitance	14-15	Evaluate small-signal capacitance for two-terminal MOS structures under varying gate voltages.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 2 (Text book 1)	Quiz, Midterm Exam, End Sem Exam	CO1, CO3
Quiz-II						
The Three-Terminal MOS Structure – Contacting the Inversion Layer, The Body Effect, Regions of Inversion, A "V_{CB} Control" Point of View, Uses for Three-Terminal MOS Structures.	16-20	Understand body effect and control mechanisms in three-terminal MOS devices and identify practical use cases.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 3 (Text book 1)	Midterm Exam, End Sem Exam	CO1, CO3
Mid-Term Examination						
The Four-Terminal MOS Transistor - Transistor Regions of Operation, Complete All-Region Model, Simplified All-Region	21-25	Model MOSFET operation across all regions using various compact models and quasi-Fermi-based approaches.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 4 (Text book 1)	End Sem Exam	CO1, CO3

Models, Models Based on Quasi-Fermi Potentials, Regions of Inversion in Terms of Terminal Voltages, Strong Inversion, Weak Inversion, Moderate-Inversion and Single-Piece Models						
Source-Referenced vs. Body-Referenced Modeling, Effective Mobility, Effect of Extrinsic Source and Drain Series Resistances, Temperature Effects, Breakdown, The p-Channel MOS Transistor, Enhancement-Mode and Depletion-Mode Transistors, Model Parameter Values, Model Accuracy, and Model Comparison.	26-30	Compare modeling approaches, analyze mobility and resistance effects, and evaluate model accuracy for different transistor types.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 4 (Text book 1)	End Sem Exam	CO1, CO3
Small-Dimension Effects - Carrier Velocity Saturation,	31-34	Identify and quantify short-channel effects and incorporate them into unified MOSFET models	Class Room Teaching - Power Point, Chalk and	Chapter 5 (Text book 1)	Quiz, End Sem Exam	CO2

Channel Length Modulation, Charge Sharing, Drain-Induced Barrier Lowering, Punchthroug h, Combining Several Small-Dimension Effects into One Model			Talk			
Quiz-III						
Hot Carrier Effects and Impact Ionization, Velocity Overshoot and Ballistic Operation, Polysilicon Depletion, Quantum Mechanical Effects, DC Gate Current, Junction Leakage, Band-to-Band Tunneling and GIDL, Leakage Currents—Particular Cases, The Quest for Ever-Smaller Devices.	35-39	Evaluate advanced device phenomena and scaling challenges including leakage, ballistic transport, and quantum effects.	Class Room Teaching - Power Point, Chalk and Talk	Chapter 5 (Text book 1)	Assignment, End Sem Exam	CO2
Assignment-I						
Large-Signal Modeling of MOS Transistor - Quasi-Static Operation,	40-43	Develop and analyze large-signal MOS models considering intrinsic/extrinsic	Class Room Teaching - Power Point, Chalk and	Chapter 6 (Text book 1)	End Sem Exam	CO1, CO3, CO4

Terminal Currents in Quasi-Static Operation, Evaluation of Intrinsic Charges in Quasi-Static Operation, Transit Time under DC Conditions, Limitations of the Quasi-Static Model, Non-Quasi-Static Modeling, Extrinsic Parasitics.		parasitics and non-quasi-static behavior.	Talk			
Overview of Modern Semiconductor Devices – SOI MOSFETs, Multi-gate Gate FETs like - Double Gate, FinFET, Gate All Around FETs (GAA-FETs).	43-45	Develop and analyze large-signal MOS models considering intrinsic/extrinsic parasitics and non-quasi-static behavior.	Class Room Teaching - Power Point, Chalk and Talk	Text Book 4	End Sem Exam	CO4

Reference(s)

1. **Y. Tsividis and C. McAndrew**, *"Operation and Modeling of the MOS Transistor"*, Oxford University Press, 2011.
2. **Donald Neamen, Dhrubes Biswas**, *" Semiconductor Physics and Devices "*, McGraw Hill, 2017.
3. **Jerry Fossum and Vishal Trivedi**, "*Fundamentals of Ultra thin body MOSFETs and FinFETs*", Cambridge University Press, 2013
4. **Jean-Pierre Colinge** "*FinFETs and other Multi Gate Transistors*", Springer (2008).
5. **Samar K. Saha**, "*Compact Models for Integrated Circuit Design - Conventional Transistors and Beyond*", CRC Press (Taylor & Francis), 2016.

13. Teaching-Learning Strategies - Class Room Teaching (Power Point, Chalk and Talk)

14. Assessment Strategy (Bloom's Taxonomy and Rubric based, Quiz, Mid Term, Assignment, Project, Report, Class Test, Presentation, Semester Final) : Assignment, Quiz, Mid-Term Exam, End Semester Exam

15. Evaluation Policy (Grading System):

Assessment	Internal	External
Midterm	30%	NA
Continuous Assessment (CA)	30%	NA
End Semester	NA	40%

Continuous Assessments

Sl. No.	Component and Maximum Marks	Weightage	Mode & Duration
1.	Quiz-I (15)	7.5	Online (15 mins)
2.	Quiz -II (15)	7.5	Online (15 mins)
3.	Quiz -III (15)	7.5	Offline (15 mins)
4.	Assignment – I (15)	7.5	Offline

Assignment Rubrics

	O	A	B	C	P	F
Submission	On time and complete	On time and partial	-	-	Late submission	No submission
Neatness	Very neat with proper labels	Very neat with no proper labels	Neat with labels	Tidy with labels	Tidy with no labels	No submission
Content	All answers are in detail and sufficient	Some of the answers are not in detail and sufficient	All answers are not in detail and sufficient	-	Incomplete	No submission

16. Make-up Procedures: One Missed Mid-Term Exam, One common quiz for those missed the quiz
17. Name & Signature of Course Instructor(s): Dr. Abhishek Raj