



<b>Lesson Plan No. 1</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: Basics Structure and Operation of MOS</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: a. understand the basic structure and operation of MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors). b. illustrate and explain the MOS symbols and their significance. c. appreciate the roles of nMOS and pMOS in circuit design and their operational differences.
<b>Teaching Aids (if any)</b>	a. Video of MOS on youtube b. Chalk and Talk
<b>Teaching Development</b>	<ol style="list-style-type: none"><li><b>Introduction (5 minutes)</b><ul style="list-style-type: none"><li>Ask questions. What do you know about transistors and their types? How does a MOSFET differ from a regular transistor? Can anyone describe the role of nMOS and pMOS transistors? Introduce the basic concept of MOSFETs. Show diagrams of nMOS and pMOS structures on slides. Highlight the importance of MOSFETs in modern electronics.</li></ul></li><li><b>Development (30 minutes)</b><ol style="list-style-type: none"><li><b>Structure of MOSFETs</b><ul style="list-style-type: none"><li>Explain the physical structure of nMOS and pMOS transistors.</li><li>Discuss the significance of the gate, drain, source, and substrate regions.</li><li>Show detailed diagrams and discuss doping types (n-type and p-type).</li></ul></li><li><b>Operation of MOSFETs</b><ul style="list-style-type: none"><li>Introduce the working principles of nMOS and pMOS transistors.</li><li>Discuss the concept of threshold voltage.</li><li>Explain how the MOSFET switches between on and off states.</li><li>Use simulation software to demonstrate the operation.</li></ul></li><li><b>MOS Symbol and Interpretation</b><ul style="list-style-type: none"><li>Show the standard symbols for nMOS and pMOS transistors.</li><li>Explain each part of the symbol (gate, source, drain, substrate connection).</li><li>Discuss how these symbols are used in circuit diagrams.</li></ul></li><li><b>Operational Differences and Applications</b><ul style="list-style-type: none"><li>Highlight the key differences between nMOS and pMOS in terms of operation.</li><li>Discuss typical applications for nMOS and pMOS transistors in circuits.</li><li>Explain the concept of complementary MOS (CMOS) technology and its advantages.</li></ul></li></ol></li></ol>



	<ol style="list-style-type: none"><li>3. Exercise (5 minutes) –<ul style="list-style-type: none"><li>- Distribute diagrams of MOS structures and symbols; ask students to label parts.</li><li>- Provide scenarios with different gate voltages; ask students to determine the MOSFET state (on/off).</li><li>- Give simple circuit diagrams; ask students to identify and explain the role of MOS transistors.</li></ul></li></ol>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading "Introduction to VLSI Systems" by Mead and Conway Online resources on MOSFETs (e.g., All About Circuits, Khan Academy)</li><li>3. Homework<ul style="list-style-type: none"><li>- Compare the structure and operation of MOSFETs with other types of transistors.</li><li>- Solve numerical problems involving threshold voltage and MOSFET operation.</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 2</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: MOS Drain Current and Threshold Voltage Equations</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ol style="list-style-type: none"> <li>understand the fundamental equations for MOSFET drain current and threshold voltage.</li> <li>illustrate how these equations are derived and applied in MOSFET design and analysis.</li> <li>apply these equations to solve practical problems in MOSFET circuit design.</li> </ol>
<b>Teaching Aids (if any)</b>	<ol style="list-style-type: none"> <li>Slides with detailed derivations and explanations of MOSFET drain current and threshold voltage equations</li> <li>Chalk and Talk</li> </ol>
<b>Teaching Development</b>	<ol style="list-style-type: none"> <li><b>Introduction</b> (5 minutes)           <ul style="list-style-type: none"> <li>Ask questions.               <p>What do you know about the role of equations in transistor design?</p> <p>Why is it important to understand the mathematical model of a MOSFET?</p> <p>How do design equations impact the performance of MOS circuits?</p> </li> <li>Introduce the concept of MOSFET drain current and threshold voltage equations.               <p>Show a brief overview of key equations on slides.</p> <p>Explain the importance of these equations in VLSI design.</p> </li> </ul> </li> <li><b>Development</b> (30 minutes)           <ol style="list-style-type: none"> <li><b>Threshold Voltage (<math>V_{th}</math>) Equation</b> <ul style="list-style-type: none"> <li>Introduce the threshold voltage and its significance in MOSFET operation.</li> <li>Present the threshold voltage equation</li> <li>Derive the threshold voltage equation on the whiteboard.</li> <li>Discuss factors affecting <math>V_{th}</math>, including substrate doping and oxide thickness.</li> </ul> </li> <li><b>Drain Current (<math>I_D</math>) Equations</b> <ul style="list-style-type: none"> <li>Explain the different regions of MOSFET operation: cutoff, triode, and saturation.</li> <li>Present the drain current equations for each region.</li> <li>Derive these equations on the whiteboard.</li> <li>Explain the physical meaning of each term in the equations.</li> </ul> </li> <li><b>Capacitance and Charge Equations</b> <ul style="list-style-type: none"> <li>Introduce gate capacitance (<math>C_{ox}C_{ox}</math>) and its significance.</li> <li>Explain the equations for gate, drain, and source capacitances.</li> <li>Discuss the impact of capacitance on switching speed and power consumption.</li> </ul> </li> </ol> </li> </ol>



	<p>d. Capacitance and Charge Equations</p> <ul style="list-style-type: none"><li>- Introduce gate capacitance (<math>C_{ox}</math>) and its significance.</li><li>- Explain the equations for gate, drain, and source capacitances.</li><li>- Discuss the impact of capacitance on switching speed and power consumption.</li></ul> <p>3. Exercise (5 minutes) –</p> <ul style="list-style-type: none"><li>- Capacitance and Charge Equations</li><li>- Introduce gate capacitance (<math>C_{ox}C_{ox}</math>) and its significance.</li><li>- Explain the equations for gate, drain, and source capacitances.</li><li>- Discuss the impact of capacitance on switching speed and power consumption.</li></ul>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading "Device Electronics for Integrated Circuits" by Richard S. Muller and Theodore I. Kamins. Online resources for MOSFET design equations (e.g., MIT OpenCourseWare).</li><li>3. Homework<ul style="list-style-type: none"><li>- Solve numerical problems involving MOSFET drain current and threshold voltage equations.</li><li>- Compare the theoretical and simulated results for MOSFET characteristics.</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 4</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: MOS I-V Characteristics Course</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ul style="list-style-type: none"> <li>a. understand the current-voltage (I-V) characteristics of MOSFETs.</li> <li>b. illustrate the I-V characteristics curves for nMOS and pMOS transistors.</li> <li>c. apply the understanding of I-V characteristics to analyze MOSFET behavior in different regions of operation.</li> </ul>
<b>Teaching Aids (if any)</b>	<ul style="list-style-type: none"> <li>a. Slides with detailed I-V characteristic curves and explanations</li> <li>b. Chalk and Talk</li> </ul>
<b>Teaching Development</b>	<ol style="list-style-type: none"> <li>1. <b>Introduction</b> (5 minutes) <ul style="list-style-type: none"> <li>- Ask questions. What do you know about the I-V characteristics of transistors? Why is understanding I-V characteristics important for MOSFET design? How do I-V characteristics influence the performance of MOS circuits?</li> <li>- Introduce the concept of MOSFET I-V characteristics. Show an overview of the key I-V curves on slides. Explain the importance of these curves in VLSI design..</li> </ul> </li> <li>2. <b>Development</b> (30 minutes) <ol style="list-style-type: none"> <li>a. Regions of Operation <ul style="list-style-type: none"> <li>- Discuss the different regions of operation for a MOSFET: cutoff, triode (linear), and saturation.</li> <li>- Explain how the MOSFET transitions between these regions based on <math>V_{GS}</math> and <math>V_{DS}</math>.</li> </ul> </li> <li>b. Cutoff Region <ul style="list-style-type: none"> <li>- Describe the cutoff region where <math>V_{GS} &lt; V_{th}</math>.</li> <li>- Present the characteristic: <math>I_D = 0</math></li> <li>- Explain the significance of this region in switching applications.</li> </ul> </li> <li>c. Triode (Linear) Region <ul style="list-style-type: none"> <li>- Describe the triode region where <math>(V_{GS} &gt; V_{th})</math></li> <li>- Present the drain current equation</li> <li>- Draw the I-V curve for the triode region</li> </ul> </li> <li>d. Saturation Region <ul style="list-style-type: none"> <li>- Draw the I-V curve for the saturation region on the whiteboard.</li> <li>- Explain the constant current behavior in the saturation region</li> </ul> </li> </ol> </li> <li>3. <b>Exercise</b> (5 minutes) – <ul style="list-style-type: none"> <li>- Distribute problems involving the identification of MOSFET</li> </ul> </li> </ol>



	<p>regions of operation from given I-V curves.</p> <ul style="list-style-type: none"><li>- Provide circuit diagrams and ask students to analyze the MOSFET behavior based on I-V characteristics</li></ul>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading CMOS Digital Integrated Circuits: Analysis and Design" by Sung-Mo Kang and Yusuf Leblebici</li><li>3. Homework<ul style="list-style-type: none"><li>- Solve numerical problems involving MOSFET I-V characteristics</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 5</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: MOS Voltage Transfer Characteristics</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: a. understand the voltage transfer characteristics (VTC) of MOSFET circuits. b. illustrate the VTC curves for nMOS and pMOS transistors. c. apply the understanding of VTC to analyze the behavior of MOSFET-based digital circuits
<b>Teaching Aids (if any)</b>	a. Video of MOS Characteristics on youtube b. Chalk and Talk
<b>Teaching Development</b>	<ol style="list-style-type: none"><li><b>1. Introduction (5 minutes)</b><ul style="list-style-type: none"><li>- Ask questions. What do you know about voltage transfer characteristics (VTC) in digital circuits? Why is understanding VTC important for MOSFET circuit design? How do VTC curves influence the performance of digital circuits?</li><li>- Introduce the concept of MOSFET voltage transfer characteristics. Show an overview of the key VTC curves on slides. Explain the importance of these curves in VLSI design.</li></ul></li><li><b>2. Development (30 minutes)</b><ol style="list-style-type: none"><li><b>a. Basic Concepts of VTC</b><ul style="list-style-type: none"><li>- Explain the concept of voltage transfer characteristics (VTC).</li><li>- Discuss the significance of VTC in determining the behavior of digital circuits.</li><li>- Show a general VTC curve on the slide and explain its key regions: low input, transition region, and high input.</li></ul></li><li><b>b. VTC of nMOS and pMOS Transistors</b><ul style="list-style-type: none"><li>- Present the VTC curve for an nMOS transistor.</li><li>- Present the VTC curve for a pMOS transistor.</li><li>- Explain the differences between the VTC of nMOS and pMOS transistors.</li></ul></li><li><b>c. CMOS Inverter VTC</b><ul style="list-style-type: none"><li>- Introduce the CMOS inverter and its importance in digital circuits.</li><li>- Present the VTC curve for a CMOS inverter.</li><li>- Explain the different regions of the CMOS inverter VTC:<ul style="list-style-type: none"><li>- Region 1: Both nMOS and pMOS are off.</li><li>- Region 2: nMOS is off, pMOS is on.</li><li>- Region 3: Both nMOS and pMOS are in the transition region.</li></ul></li></ul></li></ol></li></ol>



	<ul style="list-style-type: none"><li>- Region 4: nMOS is on, pMOS is off.</li><li>- Region 5: Both nMOS and pMOS are on.</li><li>- Draw the CMOS inverter VTC curve on the whiteboard and label the regions.</li></ul> <p>d. Practical Applications and Analysis</p> <ul style="list-style-type: none"><li>- Discuss how VTC is used to analyze the performance of digital circuits.</li><li>- Explain how to determine important parameters from VTC such as noise margins, switching threshold, and gain.</li><li>- Use simulation software to plot the VTC of a CMOS inverter.</li><li>- Analyze the VTC plot and discuss its significance in circuit design.</li><li>- .</li></ul> <p>3. Exercise (5 minutes) –</p> <ul style="list-style-type: none"><li>- Ask students to draw the VTC curve for a given MOSFET circuit.</li><li>- Provide circuit diagrams and ask students to analyze the behavior based on the VTC.</li></ul>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading<ul style="list-style-type: none"><li>- "Digital Integrated Circuits: A Design Perspective" by Jan M. Rabaey.</li><li>- Online resources on VTC of MOS circuits</li></ul></li><li>3. Homework<ul style="list-style-type: none"><li>- Ask students to draw the VTC curve for a given MOSFET circuit.</li><li>- Provide circuit diagrams and ask students to analyze the behavior based on the VTC.</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 6</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: MOS I-V Characteristics</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: a. understand the current-voltage (I-V) characteristics of MOSFETs. b. Illustrate the I-V characteristic curves for nMOS and pMOS transistors. c. Apply the understanding of I-V characteristics to analyze MOSFET behavior in different regions of operation.
<b>Teaching Aids (if any)</b>	a. Slides with detailed I-V characteristic curves and explanations. b. Chalk and Talk
<b>Teaching Development</b>	<ol style="list-style-type: none"><li><b>Introduction</b> (5 minutes)<ul style="list-style-type: none"><li>- Ask questions:<ul style="list-style-type: none"><li>- What do you know about the I-V characteristics of transistors?</li><li>- Why is understanding I-V characteristics important for MOSFET design?</li><li>- How do I-V characteristics influence the performance of MOS circuits?</li></ul></li><li>- Introduce the concept of MOSFET I-V characteristics.</li><li>- Show an overview of the key I-V curves on slides.</li><li>- Explain the importance of these curves in VLSI design.</li></ul></li><li><b>Development</b> (30 minutes)<ol style="list-style-type: none"><li>Regions of Operation<ul style="list-style-type: none"><li>- Discuss the different regions of operation for a MOSFET: cutoff, triode (linear), and saturation.</li><li>- Explain how the MOSFET transitions between these regions based on <math>V_{gs}</math> and <math>V_{ds}</math></li></ul></li><li>Cutoff Region<ul style="list-style-type: none"><li>- Describe the cutoff region where cut off occurs</li><li>- Present the characteristic:<ul style="list-style-type: none"><li>- Explain the significance of this region in switching applications</li></ul></li></ul></li><li>Triode (Linear) Region-<ul style="list-style-type: none"><li>- Describe the cutoff region where cut off occurs</li><li>- Present the characteristic<ul style="list-style-type: none"><li>- Draw the I-V curve for the triode region on the whiteboard.</li><li>- Discuss the linear relationship between <math>I_{ds}</math> and <math>V_{ds}</math></li></ul></li></ul></li><li>Challenges in CMOS inverter<ul style="list-style-type: none"><li>- Beta ratio</li><li>- noise margin and its importance</li><li>- dynamic and static power consumption.</li><li>- Propagation Delay</li><li>-Reliability Issues</li></ul></li></ol></li></ol>



	<p>3. Exercise (5 minutes) –</p> <ul style="list-style-type: none"><li>- Ask students to derive the threshold voltage for a given MOSFET.</li><li>- Provide circuit diagrams and ask students to calculate the output characteristics.</li></ul>
<b>Closure</b>	<p>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</p> <p>2. Suggested Reading "CMOS Digital Integrated Circuits: Analysis and Design" by Sung-Mo Kang and Yusuf Leblebici.</p> <p>3. Homework</p> <ul style="list-style-type: none"><li>- Solve numerical problems involving MOSFET I-V characteristics.</li><li>- Plot I-V curves for different MOSFET configurations using some software.</li></ul> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<p>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</p> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 7</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: MOS Transistor as a Switch</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ul style="list-style-type: none"> <li>a. Understand the principle of operation of a MOS transistor as a switch.</li> <li>b. Describe the switching behavior of MOS transistors in digital circuits.</li> <li>c. Apply the understanding of MOS transistor switching to design basic digital logic gates.</li> </ul>
<b>Teaching Aids (if any)</b>	<ul style="list-style-type: none"> <li>a. Slides with diagrams and explanations of MOS transistor switching.</li> <li>b. Use of simulation software to demonstrate MOS transistor switching behavior</li> </ul>
<b>Teaching Development</b>	<ol style="list-style-type: none"> <li>1. <b>Introduction</b> (5 minutes) <ul style="list-style-type: none"> <li>- Ask questions. <ul style="list-style-type: none"> <li>What is the role of a switch in digital circuits?</li> <li>How does a MOS transistor act as a switch?</li> <li>Why is MOS transistor switching important in VLSI design?</li> <li>Introduce the concept of using MOS transistors as switches.</li> </ul> </li> <li>- Explain the significance of MOS transistor switching in digital logic.</li> </ul> </li> <li>2. <b>Development</b> (30 minutes) <ol style="list-style-type: none"> <li>a. Basic Principles of Switching <ul style="list-style-type: none"> <li>- Discuss the operation of a MOS transistor as a switch.</li> <li>- Explain the role of gate voltage in turning the transistor on and off.</li> <li>- Present the concept of threshold voltage and its importance in switching behavior.</li> </ul> </li> <li>b. Cutoff and Saturation Regions <ul style="list-style-type: none"> <li>- Describe the cutoff region where the transistor is off (</li> <li>- Explain the saturation region where the transistor is fully on (saturation).</li> <li>- Illustrate these regions on the whiteboard and discuss their characteristics.</li> </ul> </li> <li>c. Logic Levels and Voltage Swing <ul style="list-style-type: none"> <li>- Discuss how MOS transistors are used to represent logic levels (0 and 1).</li> <li>- Explain the voltage swing between logic 0 and logic 1 in CMOS logic.</li> </ul> </li> <li>d. CMOS Inverter as a Switch <ul style="list-style-type: none"> <li>- Introduce the CMOS inverter and its role in digital circuits.</li> <li>- Explain the switching behavior of a CMOS inverter.</li> <li>- Discuss the operation of nMOS and pMOS transistors in the inverter.</li> </ul> </li> </ol> </li> </ol>



	<ul style="list-style-type: none"><li>- e. Switching Speed and Power Dissipation</li><li>- Discuss the factors affecting the switching speed of MOS transistors.</li><li>- Explain the concept of propagation delay and its significance.</li><li>- Discuss power dissipation during switching and methods to minimize it.</li></ul> <p>3. Exercise (5 minutes) –</p> <ul style="list-style-type: none"><li>- Distribute problems involving the determination of logic levels based on MOS transistor switching behavior.</li><li>- Ask students to design simple CMOS logic gates using MOS transistors.</li><li>- Provide circuit diagrams and ask students to analyze the switching behavior.</li></ul>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading "Digital Integrated Circuits: A Design Perspective" by Jan M. Rabaey. Online resources on MOS transistor switching</li><li>3. Homework<ul style="list-style-type: none"><li>- Solve numerical problems involving MOS transistor switching.</li><li>- Design CMOS logic gates and analyze their switching behavior.</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li><li>2. Nearpod Quiz on MOS transistor switching</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 8</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: MOS Device Capacitances</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ul style="list-style-type: none"><li>a. Define and understand the various capacitances associated with MOS devices.</li><li>b. Explain the physical mechanisms behind these capacitances.</li><li>c. Apply the knowledge of MOS device capacitances in circuit analysis and design.</li></ul>
<b>Teaching Aids (if any)</b>	<ul style="list-style-type: none"><li>a. Slides with detailed explanations and diagrams of MOS device capacitances.</li><li>b. Chalk and Talk</li></ul>
<b>Teaching Development</b>	<ol style="list-style-type: none"><li>1. <b>Introduction</b> (5 minutes)<ul style="list-style-type: none"><li>- Ask questions. What are capacitances, and how do they affect circuit behavior? Why is understanding capacitance important in MOS device design? How do different capacitances impact the performance of MOS circuits? Introduce the concept of MOS device capacitances.</li><li>- Explain the importance of capacitances in MOS device modeling and analysis..</li></ul></li><li>2. <b>Development</b> (30 minutes)<ul style="list-style-type: none"><li>a. Basic Capacitances<ul style="list-style-type: none"><li>- Define the different capacitances associated with MOS devices:<ul style="list-style-type: none"><li>- Gate-to-Source Capacitance</li><li>- Gate-to-Drain Capacitance</li><li>- Gate-to-Bulk Capacitance</li><li>- Drain-to-Source Capacitance</li></ul></li><li>- Discuss the physical mechanisms behind each capacitance.</li></ul></li><li>b. Effects of Capacitances<ul style="list-style-type: none"><li>- Discuss the impact of capacitances on MOS device performance.</li><li>- Explain how capacitances affect circuit speed, power consumption, and noise immunity.</li><li>- Illustrate the effects of capacitances on circuit behavior using simulation software.<ul style="list-style-type: none"><li>- dynamic and static power consumption.</li></ul></li><li>- Propagation Delay</li><li>- Reliability Issues</li></ul></li></ul></li><li>3. <b>Exercise</b> (5 minutes) –<ul style="list-style-type: none"><li>- Distribute problems involving the calculation of MOS device capacitances for given device dimensions and operating</li></ul></li></ol>



	<p>conditions.</p> <ul style="list-style-type: none"><li>- Ask students to analyze the effects of capacitances on circuit performance in specific scenarios.</li><li>- Provide circuit diagrams and ask students to estimate the total capacitance.</li></ul>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading "CMOS VLSI Design: A Circuits and Systems Perspective" by Neil H.E. Weste and David Money Harris. Online resources on MOS device capacitances</li><li>3. Homework<ul style="list-style-type: none"><li>- Solve numerical problems involving MOS device capacitances.</li><li>- Design MOS circuits considering capacitance effects.</li><li>-</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 9</b>	<b>Course Name: VLSI Circuit Design Topic: Introduction to CMOS Inverter</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ul style="list-style-type: none"> <li>a. articulate the concept of CMOS inverter operation</li> <li>b. illustrate its characteristics in detail.</li> <li>c. appreciate advantages of CMOS inverter over other technologies and its associated challenges</li> </ul>
<b>Teaching Aids (if any)</b>	<ul style="list-style-type: none"> <li>a. Video of CMOS inverter on youtube</li> <li>b. Use of Nearpod tool for online quiz</li> </ul>
<b>Teaching Development</b>	<ol style="list-style-type: none"> <li>1. <b>Introduction</b> (5 minutes) <ul style="list-style-type: none"> <li>- Ask questions. What is mos logic to design circuits? When does nmos is on and off? do you know at which logic pMOS is switched on and off?</li> <li>- Introduce the concept of CMOS. Show Figure on slide.</li> <li>- Talk about inverter capability.</li> <li>- Introduce the issues CMOS overcome compared to nmos and pmos. <a href="https://www.ece.ucdavis.edu/~ramirtha/EEEC118/S11/lecture4.pdf">https://www.ece.ucdavis.edu/~ramirtha/EEEC118/S11/lecture4.pdf</a></li> <li>- Highlight the important characteristics of inverter.</li> <li>- Discuss the behaviour of inverter characteristics in each region.</li> </ul> </li> <li>2. <b>Development</b> (30 minutes) <ol style="list-style-type: none"> <li>a. Issues with nMOS and pMOS <ul style="list-style-type: none"> <li>- Discuss the operations of nMOS and pMOS</li> <li>- Depending on logic0 and logic1, discuss their levels of output signals</li> </ul> </li> <li>b. CMOS inverter and its operation <ul style="list-style-type: none"> <li>- Introduce the concept of CMOS inverter.</li> <li>- Show video on its working <a href="https://www.youtube.com/watch?v=uBu-efEact8">https://www.youtube.com/watch?v=uBu-efEact8</a></li> <li>- Introduce concept of inverter operation it performs.</li> </ul> </li> <li>c. Inverter Characteristics <ul style="list-style-type: none"> <li>- Understand the nature of various regions of operation of nMOS and pMOS</li> <li>-Plot the graph based on these regions</li> <li>- Discuss this plot as inverter characteristics</li> <li>- Analyse and deliver the significance of these characteristics</li> </ul> </li> <li>d. Challenges in CMOS inverter <ul style="list-style-type: none"> <li>- Beta ratio</li> <li>- noise margin and its importance</li> <li>- dynamic and static power consumption.</li> <li>- Propagation Delay</li> <li>-Reliability Issues</li> </ul> </li> </ol> </li> </ol>



	<ol style="list-style-type: none"><li>3. Exercise (5 minutes) –<ul style="list-style-type: none"><li>- Distribute three regions of operations of inveter in class and make write the nature of operation of nMOS and pMOS</li><li>- Give logic levels for students to comment on the output for each nMOS,pMOS and CMOS.</li><li>- Give numerical on beta ratio calculation</li></ul></li></ol>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading Original NIST Paper on Cloud Computing <a href="https://www.ece.ucdavis.edu/~ramirtha/EEEC118/S11/lecture4.pdf">https://www.ece.ucdavis.edu/~ramirtha/EEEC118/S11/lecture4.pdf</a></li><li>3. Homework<ul style="list-style-type: none"><li>- Comparison between nMOS,pMOS and CMOS inverters.</li><li>- Numerical on beta ratios</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li><li>2. Nearpod Quiz on Cloud Computing</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 10</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: CMOS DC Characteristics</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ul style="list-style-type: none"> <li>a. Define and understand the DC characteristics of CMOS circuits.</li> <li>b. Describe the behavior of CMOS circuits under static conditions.</li> <li>c. Apply the knowledge of CMOS DC characteristics in circuit analysis and design.</li> </ul>
<b>Teaching Aids (if any)</b>	<ul style="list-style-type: none"> <li>a. Slides with detailed explanations and diagrams of CMOS DC characteristics.</li> <li>b. Chalk and Talk</li> </ul>
<b>Teaching Development</b>	<ol style="list-style-type: none"> <li>1. <b>Introduction</b> (5 minutes) <ul style="list-style-type: none"> <li>- Ask questions. What are DC characteristics, and why are they important in CMOS circuits? How do CMOS circuits behave under static conditions? Why is understanding DC characteristics crucial for VLSI design? Introduce the concept of CMOS DC characteristics.</li> <li>- Explain the importance of DC analysis in circuit design and optimization..</li> </ul> </li> <li>2. <b>Development</b> (30 minutes) <ol style="list-style-type: none"> <li>a. DC Operating Point <ul style="list-style-type: none"> <li>- Define the DC operating point of a CMOS circuit.</li> <li>- Explain how to determine the DC operating point using biasing techniques.</li> <li>- Discuss the impact of process variations on the DC operating point.</li> </ul> </li> <li>b. DC Transfer Characteristics <ul style="list-style-type: none"> <li>- Present the DC transfer characteristics of a CMOS inverter.</li> <li>- Explain the voltage transfer curve and its significance.</li> <li>- Discuss the slope, gain, and noise margins of the transfer curve.</li> </ul> </li> <li>c. DC Power Consumption <ul style="list-style-type: none"> <li>- Discuss the factors contributing to DC power consumption in CMOS circuits.</li> <li>- Explain the static power dissipation and its relation to device sizes and voltages.</li> <li>- Introduce techniques for minimizing static power consumption.</li> </ul> </li> </ol> </li> <li>3. <b>Exercise</b> (5 minutes) – <ul style="list-style-type: none"> <li>- Distribute problems involving the determination of DC operating points for CMOS circuits.</li> <li>- Ask students to analyze the impact of parameter variations on DC characteristics.</li> </ul> </li> </ol>



	<ul style="list-style-type: none"><li>- Provide circuit diagrams and ask students to calculate DC power consumption.</li></ul>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading CMOS Digital Integrated Circuits" by Kang and Leblebici. Online resources on CMOS DC characteristics</li><li>3. Homework<ul style="list-style-type: none"><li>- Solve numerical problems involving CMOS DC analysis.</li><li>- Design CMOS circuits with specified DC characteristics.</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 11</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: Beta Ratio Effects</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ol style="list-style-type: none"> <li>Understand the concept of beta ratio in CMOS circuits.</li> <li>Describe the impact of beta ratio on the performance of CMOS inverters.</li> <li>Apply the knowledge of beta ratio effects in optimizing CMOS circuit designs.</li> </ol>
<b>Teaching Aids (if any)</b>	<ol style="list-style-type: none"> <li>Slides with detailed explanations and diagrams of beta ratio effects</li> <li>Use of Nearpod tool for online quiz</li> </ol>
<b>Teaching Development</b>	<ol style="list-style-type: none"> <li><b>Introduction</b> (5 minutes)           <ul style="list-style-type: none"> <li>Ask questions.               <p>What is the beta ratio, and why is it important in CMOS circuits?</p> <p>How does the beta ratio affect the performance of CMOS inverters?</p> <p>Why is understanding beta ratio effects crucial for VLSI design?</p> <p>Introduce the concept of beta ratio in CMOS circuits.</p> </li> <li>Explain the significance of beta ratio in determining the switching characteristics of CMOS inverters..</li> </ul> </li> <li><b>Development</b> (30 minutes)           <ol style="list-style-type: none"> <li><b>Definition of Beta Ratio</b> <ul style="list-style-type: none"> <li>Define the beta ratio as the ratio of the width-to-length (W/L) ratios of the pMOS and nMOS transistors in a CMOS inverter.</li> <li>Discuss the impact of the beta ratio on the switching speed and power consumption of CMOS circuits.</li> </ul> </li> <li><b>Effects on Switching Characteristics</b> <ul style="list-style-type: none"> <li>Present the CMOS inverter transfer characteristics for different beta ratios.</li> <li>Explain how the beta ratio affects the voltage transfer curve and switching threshold.</li> <li>Discuss the trade-offs between speed and power consumption in CMOS inverters with different beta ratios.</li> </ul> </li> <li><b>Optimization Techniques</b> <ul style="list-style-type: none"> <li>Introduce techniques for optimizing the beta ratio in CMOS circuits.</li> <li>Discuss how adjusting the W/L ratios of pMOS and nMOS transistors can improve circuit performance.</li> <li>Present examples of optimized CMOS inverters with enhanced speed or reduced power consumption.</li> </ul> </li> </ol> </li> </ol>



	<p>3. Exercise (5 minutes) –</p> <ul style="list-style-type: none"><li>- Distribute problems involving the calculation of beta ratio effects on CMOS inverter performance.</li><li>- Ask students to analyze the impact of beta ratio variations on circuit behavior.</li><li>- Provide circuit diagrams and ask students to optimize the beta ratio for specific design goals.</li></ul>
<b>Closure</b>	<p>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</p> <p>2. Suggested Reading CMOS VLSI Design: A Circuits and Systems Perspective" by Neil H.E. Weste and David Money Harris. Online resources on beta ratio effects in CMOS circuits</p> <p>3. Homework</p> <ul style="list-style-type: none"><li>- Solve numerical problems involving beta ratio optimization in CMOS circuits.</li><li>- Design CMOS inverters with specified beta ratios to meet performance targets.</li></ul> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<p>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</p> <p>2. Nearpod Quiz on beta ratio effects in CMOS</p> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 12</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: Combinational Logic Using CMOS Logic</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ul style="list-style-type: none"><li>a. Understand the design and operation of combinational logic circuits using CMOS technology.</li><li>b. Describe the implementation of basic logic gates such as AND, OR, and XOR using CMOS transistors.</li><li>c. Apply the knowledge of CMOS combinational logic design in building complex digital circuits.</li></ul>
<b>Teaching Aids (if any)</b>	<ul style="list-style-type: none"><li>a. Slides with detailed explanations and diagrams of CMOS combinational logic circuits.</li><li>b. Chalk and Talk</li></ul>
<b>Teaching Development</b>	<ol style="list-style-type: none"><li>1. <b>Introduction</b> (5 minutes)<ul style="list-style-type: none"><li>- Ask questions:</li><li>- What is combinational logic, and how is it different from sequential logic?</li><li>- Why is CMOS technology preferred for implementing digital logic circuits?</li><li>- How do CMOS logic gates operate in a combinational logic circuit?</li><li>- Introduce the concept of combinational logic and its significance in digital circuit design.</li><li>- Explain why CMOS technology is widely used for implementing digital logic due to its low power consumption and high noise immunity..</li></ul></li><li>2. <b>Development</b> (30 minutes)<ol style="list-style-type: none"><li>a. Basic CMOS Logic Gates<ul style="list-style-type: none"><li>- Present the circuit diagrams and operation of basic CMOS logic gates:</li><li>- CMOS inverter</li><li>- CMOS NAND gate</li><li>- CMOS NOR gate</li><li>- Discuss the layout and characteristics of these gates using nMOS and pMOS transistors.</li></ul></li><li>b. Complex Logic Functions<ul style="list-style-type: none"><li>- Explain how complex logic functions such as AND, OR, and XOR can be implemented using combinations of basic CMOS gates.</li><li>- Present the circuit diagrams for implementing these functions using CMOS logic.</li><li>- Discuss the advantages of using CMOS technology for implementing complex logic functions.</li></ul></li></ol></li></ol>



	<p>c. Propagation Delay and Power Consumption</p> <ul style="list-style-type: none"> <li>- Discuss the propagation delay of CMOS logic gates and its impact on circuit performance.</li> <li>- Explain how to calculate the delay using transistor sizes and load capacitances.</li> <li>- Discuss power consumption considerations in CMOS combinational logic circuits.</li> </ul> <p>3. Exercise (5 minutes) –</p> <ul style="list-style-type: none"> <li>- Distribute problems involving the design and analysis of CMOS combinational logic circuits.</li> <li>- Ask students to design specific logic functions using CMOS gates.</li> </ul>
<b>Closure</b>	<ol style="list-style-type: none"> <li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li> <li>2. Suggested Reading "Digital Design: Principles and Practices" by John F. Wakerly. Online resources on CMOS combinational logic design</li> <li>3. Homework <ul style="list-style-type: none"> <li>- Design and simulate CMOS combinational logic circuits for given logic functions.</li> </ul> </li> </ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"> <li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li> </ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 13</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: NAND, NOR Gates, and</b> <b>Compound Gates in CMOS</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ol style="list-style-type: none"> <li>Understand the design and operation of NAND and NOR gates using CMOS technology.</li> <li>Describe the implementation of compound logic gates such as AND-OR-INVERT (AOI) and OR-AND-INVERT (OAI) using CMOS transistors.</li> <li>Apply the knowledge of CMOS gates in building complex digital circuits.</li> </ol>
<b>Teaching Aids (if any)</b>	<ol style="list-style-type: none"> <li>Slides with detailed explanations and diagrams of CMOS NAND, NOR, and compound gates.</li> <li>Use of Nearpod tool for online quiz</li> </ol>
<b>Teaching Development</b>	<ol style="list-style-type: none"> <li><b>Introduction</b> (5 minutes)           <ul style="list-style-type: none"> <li>What are NAND and NOR gates, and why are they important in digital logic?</li> <li>How are NAND and NOR gates implemented using CMOS technology?</li> <li>What are compound gates, and how do they differ from basic gates?</li> <li>Introduce the concept of NAND and NOR gates and their significance in digital circuit design.</li> <li>Explain the advantages of using CMOS technology for implementing complex logic functions.</li> <li>.</li> </ul> </li> <li><b>Development</b> (30 minutes)           <ol style="list-style-type: none"> <li><b>CMOS NAND Gate</b> <ul style="list-style-type: none"> <li>Present the circuit diagram and operation of a CMOS NAND gate.</li> <li>Explain how the NAND gate is constructed using a series connection of nMOS transistors and a parallel connection of pMOS transistors.</li> <li>Discuss the truth table and voltage transfer characteristics of the CMOS NAND gate.</li> </ul> </li> <li><b>CMOS NOR Gate</b> <ul style="list-style-type: none"> <li>Present the circuit diagram and operation of a CMOS NOR gate.</li> <li>Explain how the NOR gate is constructed using a parallel connection of nMOS transistors and a series connection of pMOS transistors.</li> <li>Discuss the truth table and voltage transfer characteristics of the CMOS NOR gate.</li> </ul> </li> </ol> </li> </ol>



	<p>c. Compound Gates: AOI and OAI</p> <ul style="list-style-type: none"><li>- Introduce compound gates such as AOI (AND-OR-INVERT) and OAI (OR-AND-INVERT).</li><li>- Present the circuit diagrams and truth tables of AOI and OAI gates.</li><li>- Discuss the advantages of compound gates in reducing circuit complexity and area.</li></ul> <p>3. Exercise (5 minutes) –</p> <ul style="list-style-type: none"><li>- Distribute problems involving the design and analysis of CMOS NAND, NOR, AOI, and OAI gates.</li><li>- Ask students to design specific logic functions using these gates.</li></ul>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading "CMOS Digital Integrated Circuits: Analysis and Design" by Sung-Mo Kang and Yusuf Leblebici. Online resources on CMOS gate design</li><li>3. Homework<ul style="list-style-type: none"><li>- Distribute problems involving the design and analysis of CMOS NAND, NOR, AOI, and OAI gates.</li><li>- Ask students to design specific logic functions using these gates.</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li><li>2. Nearpod Quiz on CMOS gate design and compound gates.</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>



<b>Lesson Plan No. 14</b>	<b>Course Name: VLSI Circuit Design</b> <b>Topic: Pass Transistor Logic</b>	<b>Course No.: ECE-602</b>
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<b>Objectives</b>	At the end of the lesson the student shall be able to: <ol style="list-style-type: none"> <li>Understand the concept of pass transistor logic and its advantages.</li> <li>Describe the operation and characteristics of transmission gates and pass-transistor logic gates.</li> <li>Apply the knowledge of pass transistor logic in digital circuit design.</li> </ol>
<b>Teaching Aids (if any)</b>	<ol style="list-style-type: none"> <li>Slides with detailed explanations and diagrams of pass transistor logic.</li> <li>Chalk and Talk</li> </ol>
<b>Teaching Development</b>	<ol style="list-style-type: none"> <li><b>Introduction (5 minutes)</b> <ul style="list-style-type: none"> <li>Ask questions:               <ul style="list-style-type: none"> <li>What is pass transistor logic, and why is it used in digital circuits?</li> <li>How does pass transistor logic differ from conventional CMOS logic?</li> <li>What are the advantages and disadvantages of using pass transistor logic?</li> </ul> </li> <li>Introduce the concept of pass transistor logic and its significance in digital circuit design.</li> <li>Explain the advantages of pass transistor logic in terms of reduced area and improved speed..</li> </ul> </li> <li><b>Development (30 minutes)</b> <ol style="list-style-type: none"> <li><b>Transmission Gate</b> <ul style="list-style-type: none"> <li>Present the circuit diagram and operation of a transmission gate.</li> <li>Explain how the transmission gate is constructed using a parallel connection of nMOS and pMOS transistors.</li> <li>Discuss the truth table and characteristics of the transmission gate.</li> </ul> </li> <li><b>Pass-Transistor Logic Gates</b> <ul style="list-style-type: none"> <li>Present the circuit diagrams and operation of pass-transistor logic gates such as pass gates, pass-transistor XOR gates, and pass-transistor multiplexers.</li> <li>Explain how pass-transistor logic gates are constructed using transmission gates.</li> <li>Discuss the advantages of pass-transistor logic gates in terms of reduced area and improved speed compared to conventional CMOS gates.</li> </ul> </li> <li><b>Performance Comparison</b> <ul style="list-style-type: none"> <li>Compare the performance of pass transistor logic with conventional CMOS logic in terms of area, speed, and power</li> </ul> </li> </ol> </li> </ol>



	<p>consumption.</p> <ul style="list-style-type: none"><li>- Discuss the trade-offs involved in selecting between pass transistor logic and CMOS logic for different applications</li></ul> <p>3. Exercise (5 minutes) –</p> <ul style="list-style-type: none"><li>- Distribute problems involving the design and analysis of pass transistor logic circuits.</li><li>- Ask students to design specific logic functions using pass-transistor logic gates.</li></ul>
<b>Closure</b>	<ol style="list-style-type: none"><li>1. Summarize the Lesson Learning Outcomes and get affirmation from students on these.</li><li>2. Suggested Reading "Digital Integrated Circuits: A Design Perspective" by Jan M. Rabaey. Online resources on pass transistor logic design</li><li>3. Homework<ul style="list-style-type: none"><li>- Design and simulate pass transistor logic circuits for given logic functions.</li><li>- Analyze the performance and area overhead of pass-transistor logic gates.</li></ul></li></ol> <p>Spend 5 minutes to wrap up and consolidate the learnings</p>
<b>Evaluation</b>	<ol style="list-style-type: none"><li>1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss.</li></ol> <p>Spend 5 minutes to evaluate student assimilation of the lesson contents</p>