ELEN90043 Device Models

Credit Points:	12.50
Level:	9 (Graduate/Postgraduate)
Dates & Locations:	This subject is not offered in 2014.
Time Commitment:	Contact Hours: 1 two hour lecture per week Total Time Commitment: 200 hours
Prerequisites:	Admission into the MC-NE Master of Nanoelectronic Engineering OR Admission into a postgraduate course offered by the Melbourne School of Engineering, subject to program coordinator approval
Corequisites:	None
Recommended Background Knowledge:	Basic knowledge and understanding of electronics
Non Allowed Subjects:	None
Core Participation Requirements:	For the purposes of considering request for Reasonable Adjustments under the Disability Standards for Education (Cwth 2005), and Students Experiencing Academic Disadvantage Policy, academic requirements for this subject are articulated in the Subject Description, Subject Objectives, Generic Skills and Assessment Requirements of this entry. The University is dedicated to provide support to those with special requirements. Further details on the disability support scheme can be found at the Disability Liaison Unit website: http://www.services.unimelb.edu.au/disability/
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Subject Overview:	**AIMS** This subject introduces students to the fundamental principles of conventional and advanced transistor and nanodevice modelling. This subject discusses different transport mechanisms in micro and nano-metre scale devices. Devices include conventional transistors (NMOS, PMOS), double gate transistors, FinFET and Varactors and other active devices are the building blocks of microelectronic and nanoelectronic. This subject will provide the student with the latest models of these devices operating in the multi-gigahertz and sub-threshold regions. Students will be able to design and analyse simple circuits using these models. **INDICATIVE CONTENT** Topics include: - Semiconductor Fundamentals: Semiconductor materials, different kinds, physical and chemical properties. Energy bands of semiconductors, electrons and holes, doping, carrier densities, carrier transport (drift, mobility, diffusion and currents). Recombination and generation. Diffusion length and continuity equation. Photoelectric effects. - Contact Phenomena: Appearance of potential barrier on the example of metal-electronic semiconductor contact. Current density. Einstein connection. Balance conditions of contacting bodies. Balance conditions of contacted bodies. Accumulated contact layer in the absence of current. Ohmic contacts. - P-N Junction: P-N junction structure and principle of operation. Energy band diagram. Thermal equilibrium. The built-in potential. Forward and reverse bias. The P-N junction currents. Voltage-current characteristics. Diffusion and barrier capacitances. The characteristics of the real diode. Recombination-generation current. I-V characteristics of real P-N diode. General breakdown characteristics. Tunnel, avalanche, and thermal breakdown. Time response of P-N diode. The transient properties of diodes. Equivalent circuit of diode. Parameters dependence on temperature. Types of semiconductor diodes. Quantum well structures. - Metal-Semiconductor Junctions: Structure and principle of operation. Energy band diagram. Thermal equilibrium. The built-in potential. Forward and reverse bias. Voltage-current

characteristics. Schotky barrier diode parameters. Linear metal-semiconductor contact. Ohmic and tunnel contacts.

Nanoelectronic Devices: Reduction in the size of conventional field-effect transistors. Next-generation electronics devices. Resonant tunnelling devices and single-electron transistor. Operation principles and functional capabilities.

Bipolar Junction Transistors: Structure and principle of operation, Energy band diagram. Static characteristics and parameters of bipolar transistors. Ideal transistor model. Forward active mode of operation, general bias modes of operation. The Ebers-Moll model. Saturation. Secondary effects in real devices. Base width modulation, punch-through and thermal effects, recombination in the depletion region. Gummel-Poon model. Charge-control analysis. BJT dynamic performance. Transit time effects. Equivalent transistor circuits and determination of their components values by means of physical parameters.

Metal-semiconductor field effect transistors: Structure and principles of operation. MOSFET analysis. The linear, quadratic and variable depletion layer models. Parameters and characteristics. Threshold voltage calculation, the substrate bias effect. Performance limitations. SPICE models of MOS transistors. Structure of CMOS transistors, operation principles, characteristics, models, impact of technological peculiarities on their characteristics. Advanced MOSFET issues, channel length modulation. Short channel effects, sub-threshold current, field dependent mobility, punch through, velocity saturation, bipolar action, oxide injection etc.

Metal-Oxide-Semiconductor (MOS) Capacitors: Structure and principles of operation. Energy band diagram. Accumulation, depletion and inversion modes. MOS analysis.

Photo and Optoelectronic Devices MOS Field Effect Transistors: Structure and principles of operation. MOSFET analysis. The linear, quadratic and variable depletion layer models. Parameters and characteristics. Threshold voltage calculation, the substrate bias effect. Performance limitations. SPICE models of MOS transistors. Structure of CMOS transistors, operation principles, characteristics, models, impact of technological peculiarities on their characteristics. Advanced MOSFET issues, channel length modulation. Short channel effects, sub-threshold current, field dependent mobility, punch through, velocity saturation, bipolar action, oxide injection etc.

Learning Outcomes:	**INTENDED LEARNING OUTCOMES (ILO)** The goal of the course is to teach the future designers the principles of operation, design and construction of contemporary semiconductor devices created on the basis of solid state physical effects. Having completed this subject it is expected that the student be able to: 1 Explain the different types of semiconductor devices used in the VLSI; 2 Use device modeling approaches for different transport mechanisms and technology nodes; 3 Describe device structures, operation principles, characteristics and computer models, as well as acquaintance with the peculiarities of models introduction in EDA and application of semiconductor devices; 4 Choose the right model for a device and its operating regime; 5 Estimate device performance and noise parameters and use this to design circuits.
Assessment:	One written examination (not exceeding three hours) at the end of semester, worth 70%; Continuous assessment of submitted project work (not exceeding 30 pages in total over the semester), worth 30%. All Intended Learning Outcomes (ILOs) are assessed in the final written examination and submitted design project reports.
Prescribed Texts:	None
Breadth Options:	This subject is not available as a breadth subject.
Fees Information:	Subject EFTSL, Level, Discipline & Census Date, http://enrolment.unimelb.edu.au/fees
Generic Skills:	# Ability to apply knowledge of science and engineering fundamentals # Ability to undertake problem identification, formulation, and solution # Ability to utilise a systems approach to complex problems and to design andoperationalperformance # Ability to build and test real world systems that meet industry specialisation and manufacturing standards

	# Capacity for lifelong learning and professional development
Notes:	**LEARNING AND TEACHING METHODS** The subject is delivered through lectures. **INDICATIVE KEY LEARNING RESOURCES** Students are provided with lecture slides and a problem set and solutions and reference text list. **CAREERS / INDUSTRY LINKS** Exposure to microelectronic industry through research lab visits and/or guest lectures.
Related Course(s):	Master of Nanoelectronic Engineering