6.012 - Microelectronic Devices and Circuits

GENERAL THEME: *Modeling/Design*

TOPICS:

Charge Carriers and Transport

Electrons and holes in semiconductors; generation and recombination; intrinsic conductivity. Doping; detailed balance and mass action; extrinsic carrier concentration; p- and n-type semiconductors. Excess carriers; recombination; low level injection and minority carrier lifetime. Drift; mobility and conductivity; photoconductivity. Diffusion; the Einstein relation, quasi-neutrality, and dielectric relaxation; role of minority carriers.

P-N Junctions

Space charge in inhomogeneously doped semiconductor. Poisson-Boltzmann equation; Debye length. Depletion approximation. Boundary conditions at edge of space charge layer. Diode i-v characteristics. Depletion and diffusion capacitances. Incremental equivalent circuit. Light emitting diodes. Optical injection of carriers; photodiodes; solar cells.

Bipolar Transistors

Derivation of large signal forward active region model; base width modulation. Hybrid-π incremental model including Early effect and capacitive elements; intrinsic high frequency limitations of BJTs.

MOS Field Effect Transistors

MOS capacitor: accumulation, depletion, inversion, strong inversion with depletion approximation; factors that control threshold voltage. MOS transistors: gradual channel approximation; i-v characteristics in strong inversion; channel length modulation; velocity saturation. Incremental model including Early effect, back gate effect, and capacitive elements; intrinsic high frequency limitations of MOSFETs. Sub-threshold physics; drain current; LEC; comparison to BJT.

Transistor Circuits

Digital building-block circuits; MOS and bipolar inverter technologies; CMOS; memory cells. Switching transients and gate delays.

Various single stage MOSFET and BJT amplifier configurations; resistor and current source biasing. Current source design. Resistive, current source, and active loads. Multistage amplifiers; differential pairs; direct-coupled stages. Frequency response; Miller effect; methods of open circuit and short circuit time constants. Subthreshold amplifier design and applications.

Use of SPICE as a circuit modeling tool.

NOTE: The order in which topics are presented above does not necessarily represent the order in which they will be discussed in class.

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