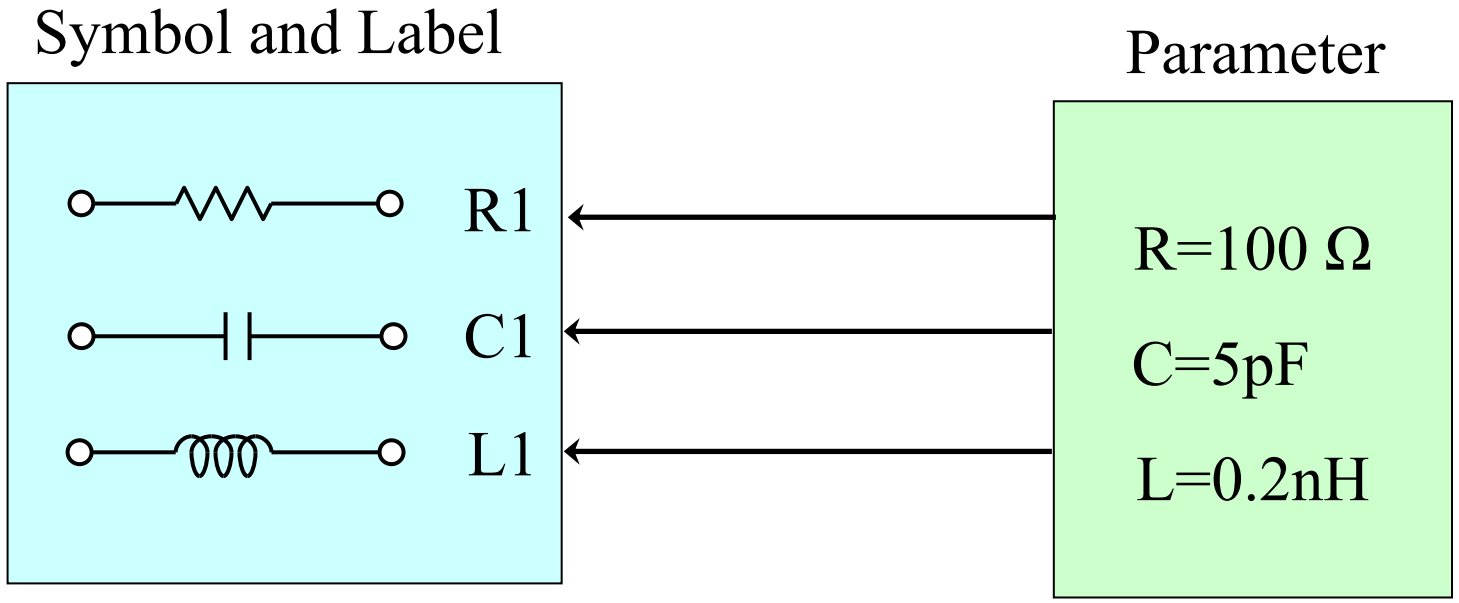
4.3 Device model of MOSFET

Mathematical model of MOSFET for
a circuit simulation

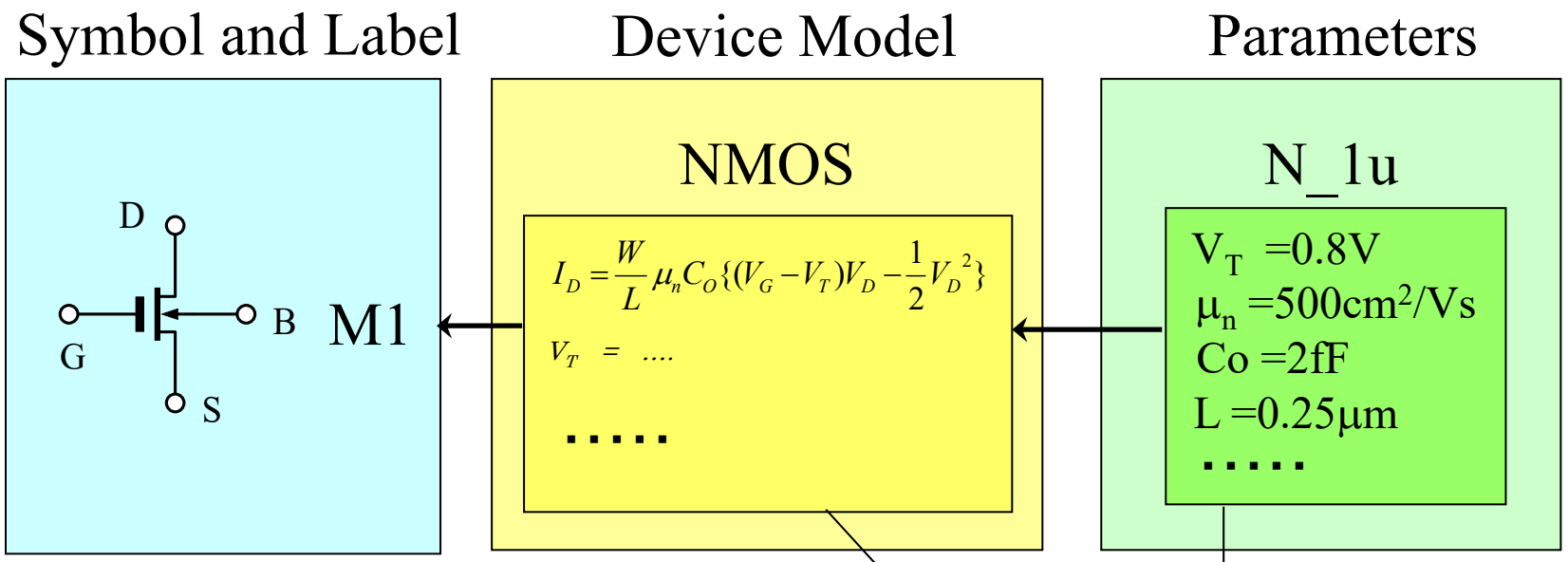
Model of passive components



The passive elements is characterized by one parameter, if you do not consider the temperature coefficient.

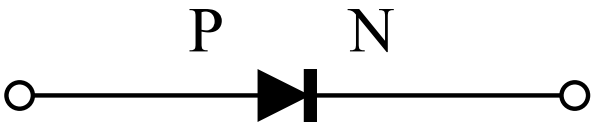
Model of semiconductor devices

A device model and model parameters of semiconductor devices



A characteristics of semiconductor devices = Device model + Parameters.
Example of n-ch MOSFET: .MODEL N_1u NMOS (Parameters …)

Model of pn junction



Symbol of on junction (Diode)

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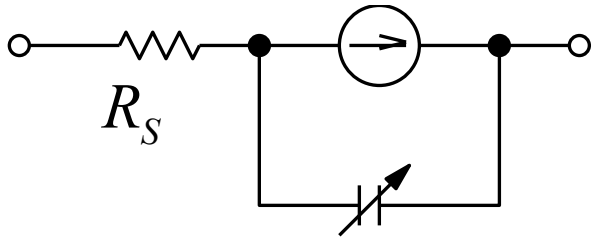
$$I_{PN} = I_S\left(e^{\frac{q \cdot V_{PN}}{k \cdot T}} - 1\right)$$

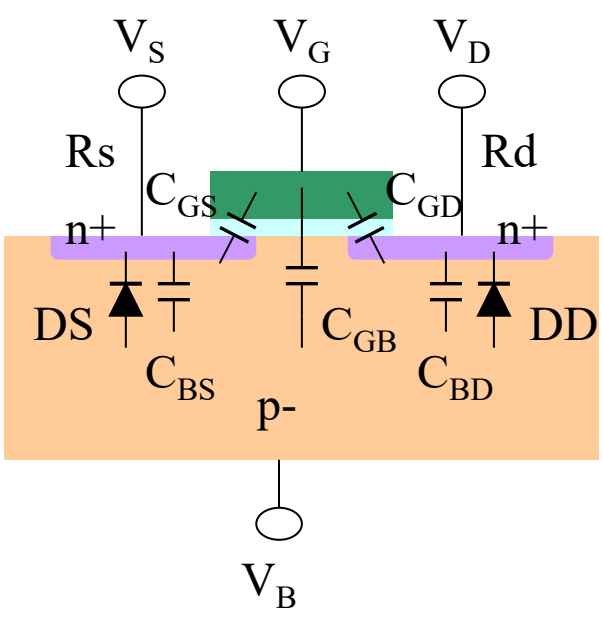


$$C_{PN} = \varepsilon_0 \varepsilon_{Si} \frac{S}{d} = \frac{C_{PN}(0V)}{\sqrt{1 - \frac{V_{PN}}{V_B}}}$$

The parameters R_S, C_{PN}(0V), I_S , and V_B are estimated by a measured characteristics.

Device model of MOSFET

The device model is defined as a set of formulas: I-V characteristics of MOSFET and pn junction, C-V characteristics of parasitic capacitances, and series resistances.



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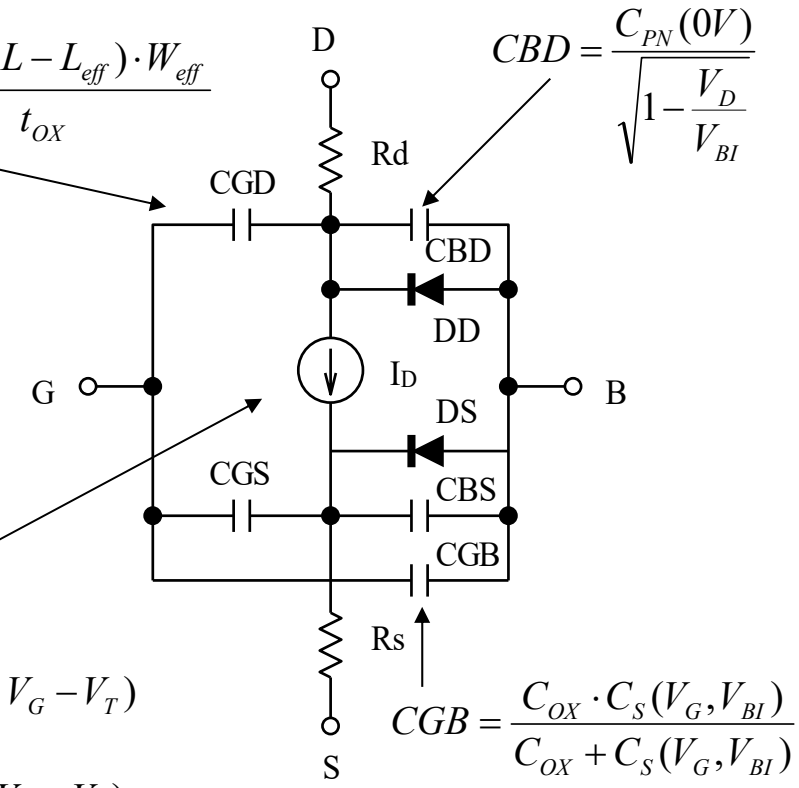

$$CGD = \frac{\varepsilon_0 \varepsilon_{SiO_2} (L - L_{eff}) \cdot W_{eff}}{t_{OX}}$$

$$CBD = \frac{C_{PN}(0V)}{\sqrt{1 - \frac{V_D}{V_{BI}}}}$$

$$\begin{cases} I_D = \beta_n \{(V_G - V_T)V_D - \frac{1}{2}V_D^2\} & (V_D < V_G - V_T) \\ I_D = \frac{\beta_n}{2}(V_G - V_T)^2(1 + \lambda V_D) & (V_D \geq V_G - V_T) \end{cases}$$

$$CGB = \frac{C_{OX} \cdot C_S(V_G, V_{BI})}{C_{OX} + C_S(V_G, V_{BI})}$$

Differences of circuit simulation and logic simulation

- Circuit simulation
  - is used for a detailed verification of analog and digital circuits.
  - requires a transistor schematic and a wave form of an input signal.
  - finds a numerical solution of a circuit equations.
  - is a close-to-reality simulation based on a semiconductor characteristics.
  - takes very long time to calculate.

- Logic simulation
  - is used for a functional and timing verification of a logic.
  - requires a HDL description and a input vector of logic values.
  - find a timing diagram with time slice accuracy.
  - can be estimate a circuit performance of a logic, but the simulation accuracy depends on that of the propagation delay data of each gate.
  - is completed in a relatively short time.
  - has no ability to simulate an analog circuit.