

EE-429

Fundamentals of VLSI Design

Spice Simulations

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Need for Circuit Simulations

- **Circuit simulators are important to**
 - Verify that our designs are properly working (verification)
 - Extract circuit parameters for high-level models for design and optimization
 - Fine tune parameters from an initial hand-crafted (model-based) starting point
 - Verify a circuit in different corners and in the presence of uncertainties
 - Track down hidden issues in a larger circuit (especially post-layout)
- **They should not serve as a basis for pure trial-and-error**
 - Analog simulation are too slow for extensive trial and error
 - At any stage, you need to have a good idea of “what to expect”
 - You should have a good (and well justified) starting point

The Original of Circuit Simulations

- **First circuit simulator was developed in the 1970s at Berkely:**
 - Started as a class project: **CANCER**="Computer Analysis for Non-linear Circuits Excluding Radiation" (under Prof. Ron Rohrer)
 - His successor (Prof. **Don Peterson**) and his student (**Larry Nagel**) **developed** this class project into **the first version of Spice**
 - **1972 Spice** was released as "**Public Domain**" (free SW), written in FORTRAN
 - **1975 Spice 2:** support for hierarchy, better stability and much less basic device models
 - **1989 Spice 3:** better UI, advanced MOSFET (BSIM1 models), written in C
 - **SPICE:** Bimulation **P**rogram with **I**ntegrated **C**ircuit **E**mphasis
- **Today, there are many versions of Spice**, including "famous" commercial simulators
 - **LTSpice, PSpice:** public domain
 - **HSpice:** today owned by Synopsys
 - **SPECTRE:** developed by CADENCE

Setting up a Simulation

- **For an analog (e.g., Spice) circuit information, we need**
 - A “**Netlist**” that describes our circuit
 - A “**Testbench**” to provide stimuli, supply voltages, and other inputs as well as external components that connect to our DUT (e.g., capacitive loads,...).
 - “**Device models**” for basic components: part of the simulator
 - “**Model parameters**”: part of the PDK:
 - **Initial conditions**: The state of our circuit at the start of the simulation
 - **Instructions what and how to simulate** and simulation parameters (e.g., temperature)
 - **Instructions what to record/save** and plot

```
INVERTER TRANSIENT ANALYSIS
*****
• MODELS *
• *****
• .model NMOD NMOS (LEVEL=1, VTO=0.7 GAMMA=0 LAMBDA=0
  KP=73U)
• .model PMOD PMOS (LEVEL=1, VTO=-0.8 GAMMA=0 LAMBDA=0
  KP=21U)
• *****
• * CIRCUIT *
• *****
• VDD 3 0 DC 5
• VGS 1 0 PULSE(0,5,0,5n,5n,1u,2u)
• M1 2 1 0 0 NMOD L=2U W=10U
• M2 2 1 3 3 PMOD L=2U W=25U
• C1 2 0 0.047n
• .OP
• .TRAN 0.1U 3U
• .PLOT TRAN V(2)
• .PROBE
• .END
```

Types of Simulations

- **DC Analysis**

- Find the **DC Operating Point**: circuit solution in steady state (all inputs fixed)
- Solves a non-linear system of equations: usually through **linearization** and **Newton's method**
- Iterative process that converges to a solution
- The DC analysis is the **starting point for a Transient or AC Analysis**

- **Transient Analysis**

- Starts from operating point found in DC analysis (time-0)
- **Solves** a set of **non-linear differential equations by discretising time** usually with variable time steps

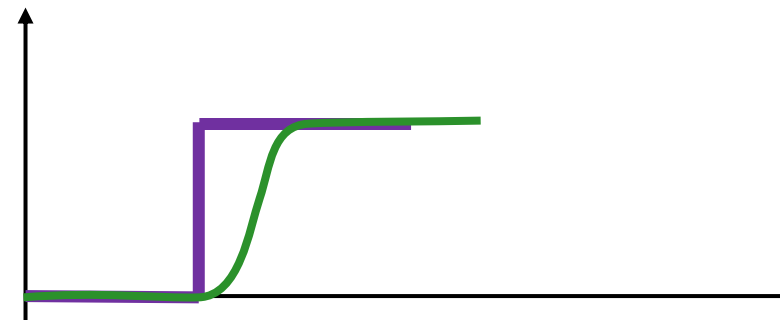
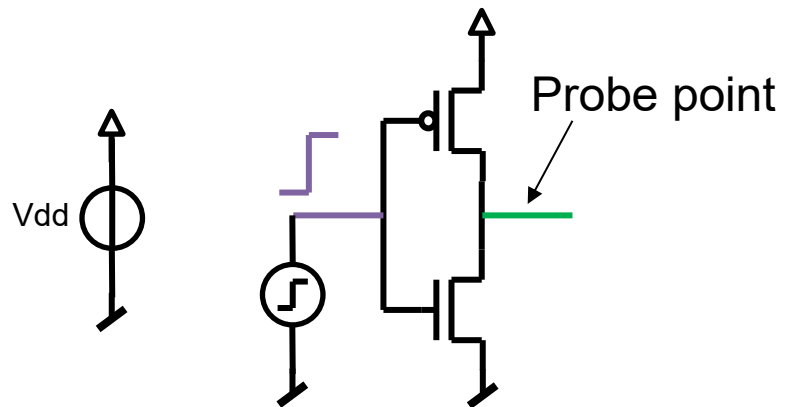
- **AC Analysis**

- Used mostly for analog design
- **Analyzes frequency domain behavior** / response of a circuit

Creating a Proper Testbench

- A **proper testbench** (adapted to what we want to see) **is critical** to have meaningful results

Example: delay (transient) simulation of an inverter

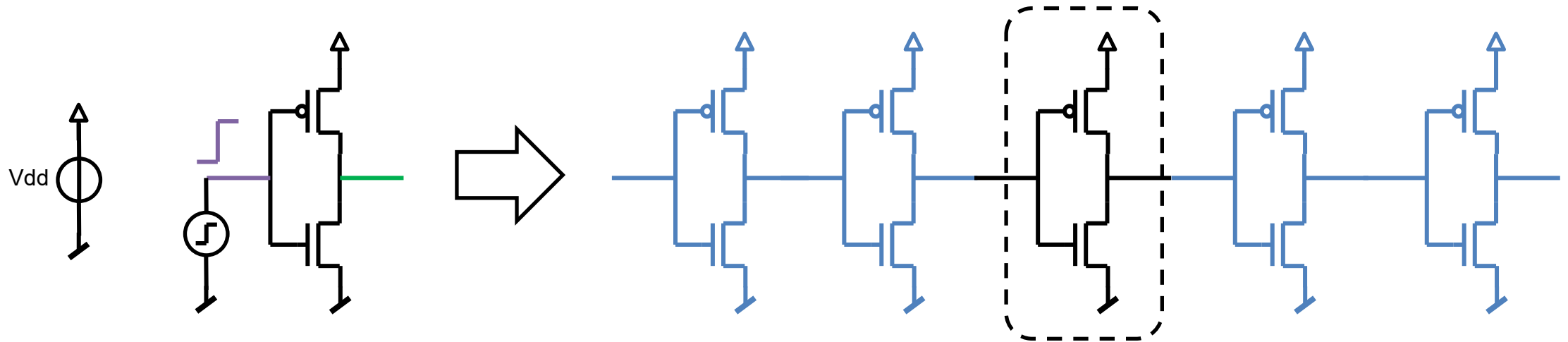


What is missing here?

Creating a Proper Testbench

- A **proper testbench** (adapted to what we want to see) **is critical** to have meaningful results
- **Must properly reflect not only the circuit, but also the boundary conditions**
 - Realistic input signals
 - Realistic electrical characteristics of the inputs and outputs

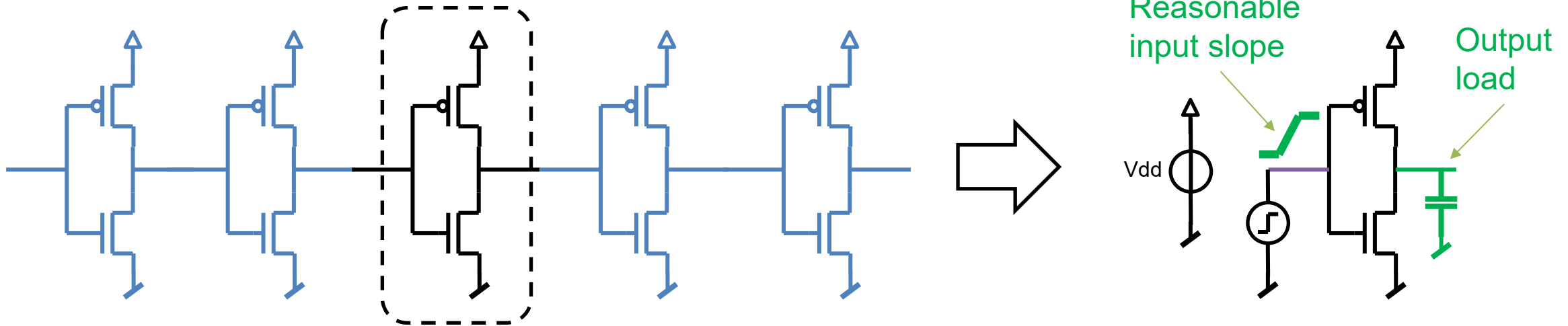
Example: delay (transient) simulation of an inverter



Creating a Proper Testbench

- A **proper testbench** (adapted to what we want to see) **is critical** to have meaningful results
- **Must properly reflect not only the circuit, but also the boundary conditions**
 - Realistic input signals
 - Realistic electrical characteristics of the inputs and outputs
- **Efficiently represent boundary conditions with a proper model**

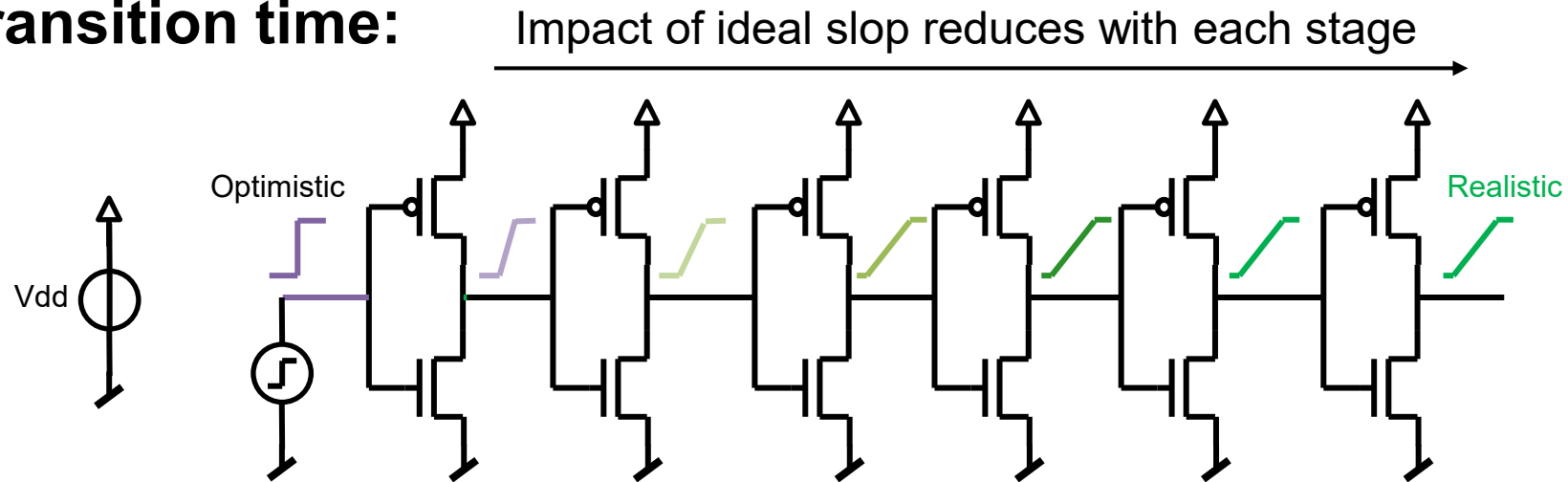
Example: delay (transient) simulation of an inverter



Creating a Proper Testbench

- Using simulation to **find proper values for transition time and output load:**
 - Build a testbench that allows to calculate the desired model parameters from known quantities

- **Input transition time:**



Creating a Proper Testbench

- Using simulation to **find proper values for transition time and output load:**
 - Build a testbench that allows to calculate the desired model parameters from known quantities
- **Load capacitance:**
 - Extract from RC model

