Open-Source IC Design Workshop

1.3 Open-source analog design tools

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AC3E

UCU Universidad Católica del Uruguay

Agenda

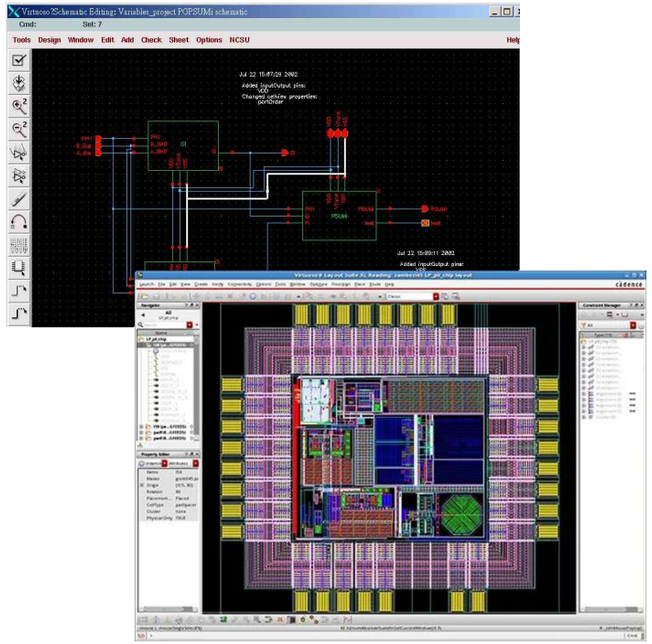
- Introduction
- Open-source analog design tools
- Simulation examples

Introduction

Introduction

IC design: from manual to automated

< 1990s → fully manual chip design!



> 1990s → EDA tools

Google + skywater TECHNOLOGY

FOSS 130nm Production PDK
github.com/google/skywater-pdk

IHP-GmbH/**IHP-Open-PDK-docs**

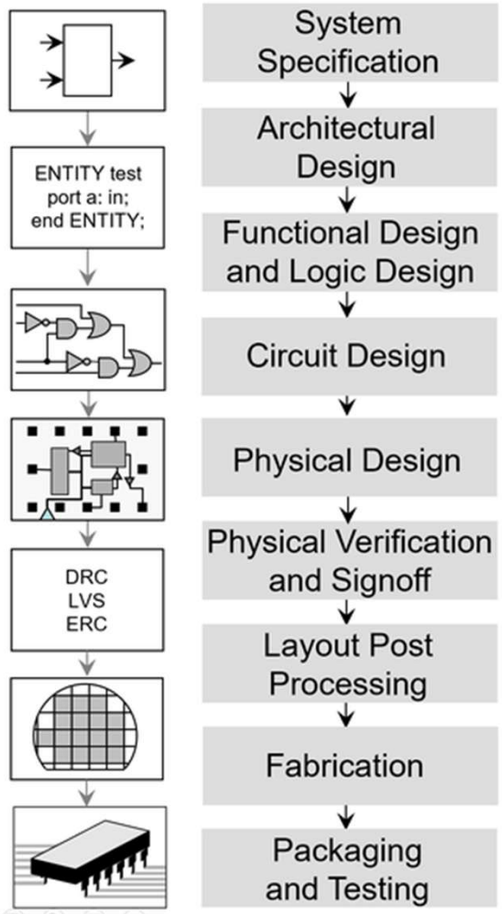
Documentation for IHP 130nm BiCMOS Open Source PDK

> 2020 → Opensource EDA tools and PDKs

Analog vs digital design flows

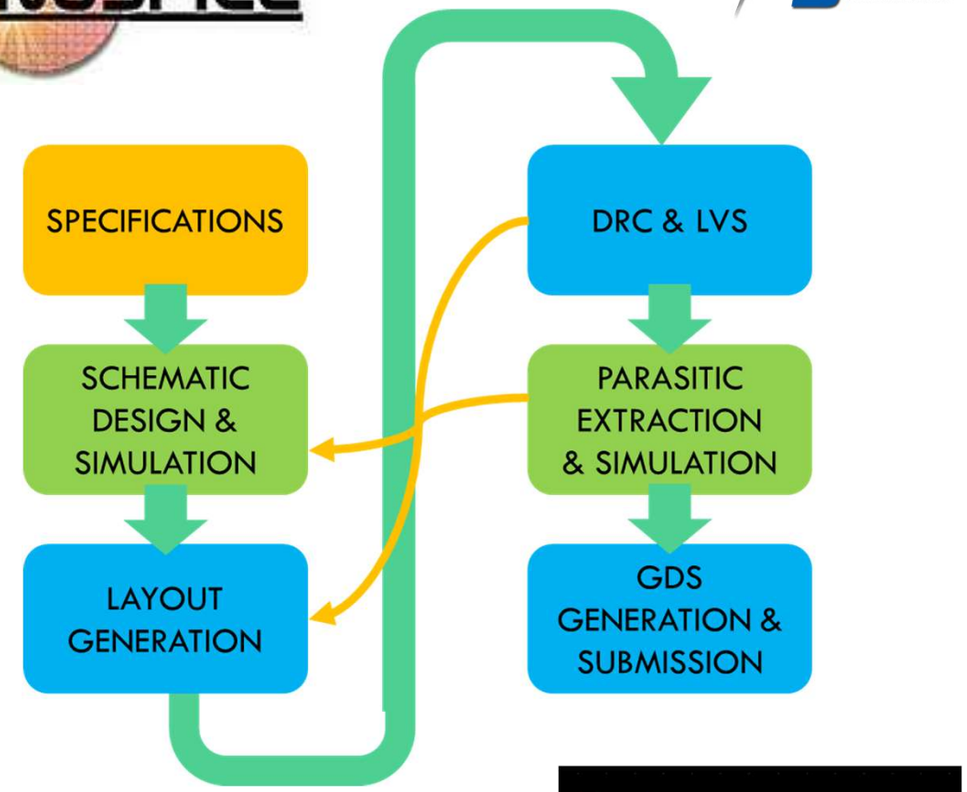
IC design flow: digital versus analog

DIGITAL FLOW



System Specification
Architectural Design
Functional Design and Logic Design
Circuit Design
Physical Design
Physical Verification and Signoff
Layout Post Processing
Fabrication
Packaging and Testing

ANALOG FLOW



NGSPICE

Xyce PARALLEL ELECTRONIC SIMULATOR

XSCHEM

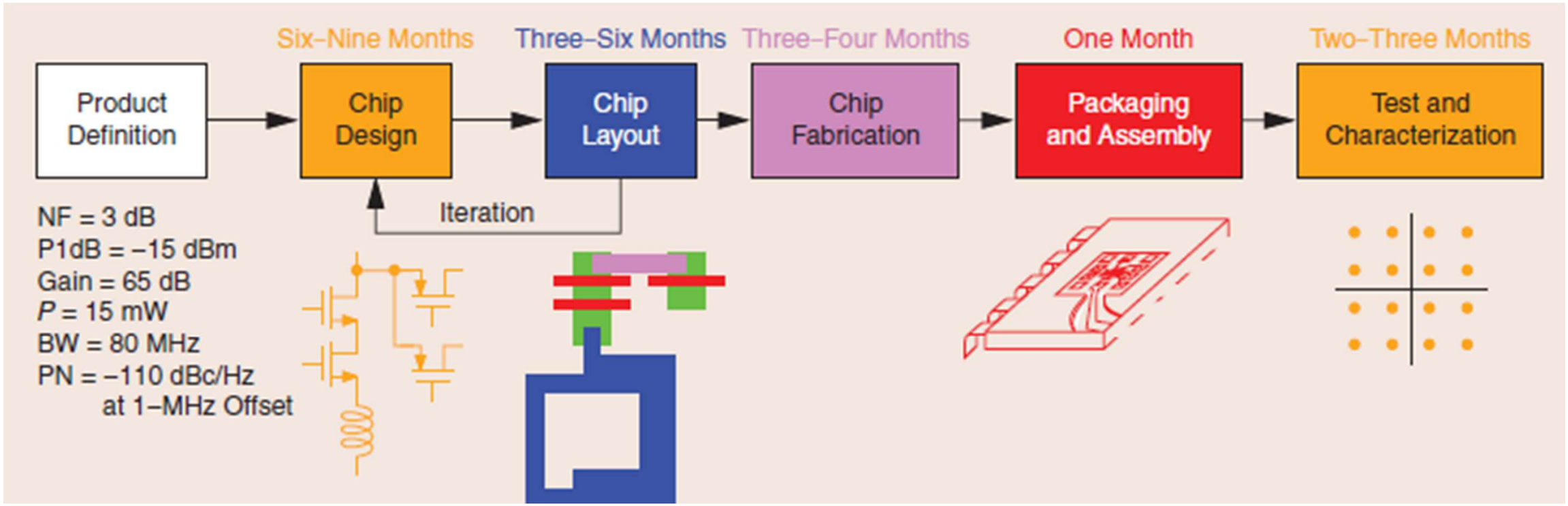
Yosys

OpenROAD 24h

Magic VLSI Layout Tool
Current distribution version 8.2

Introduction

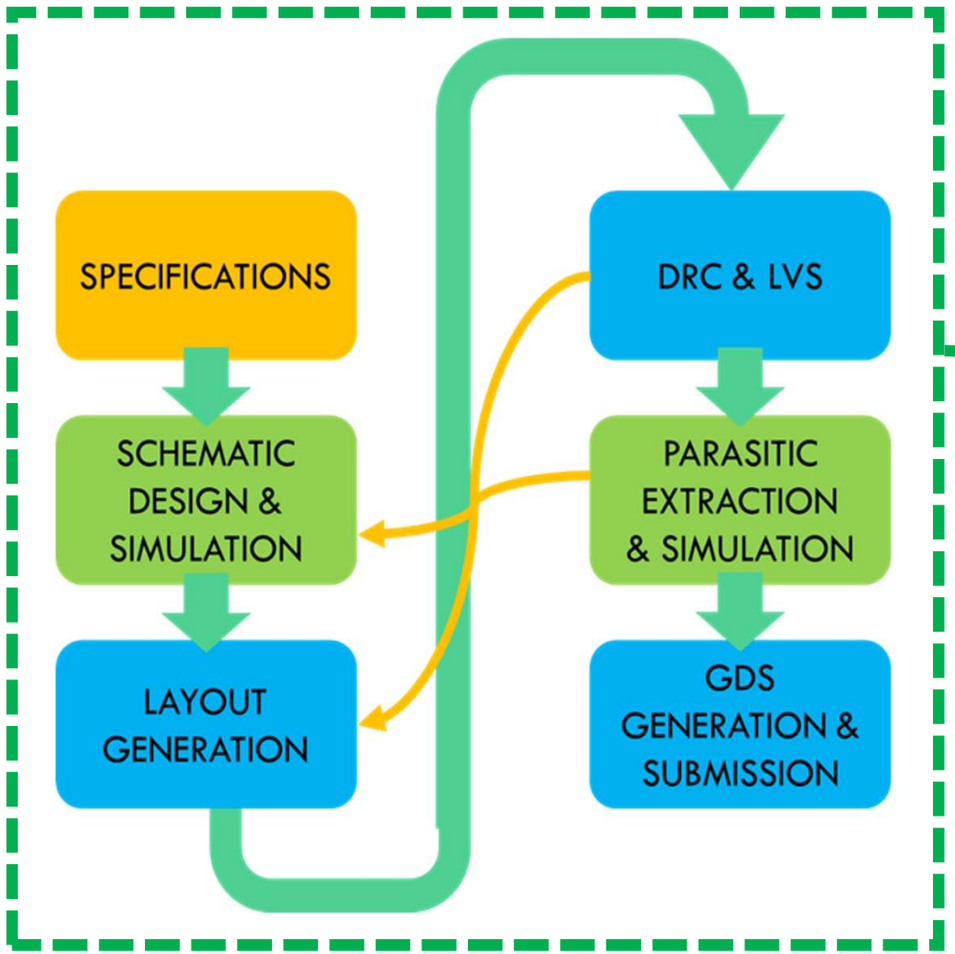
Silicon-proven analog IC design

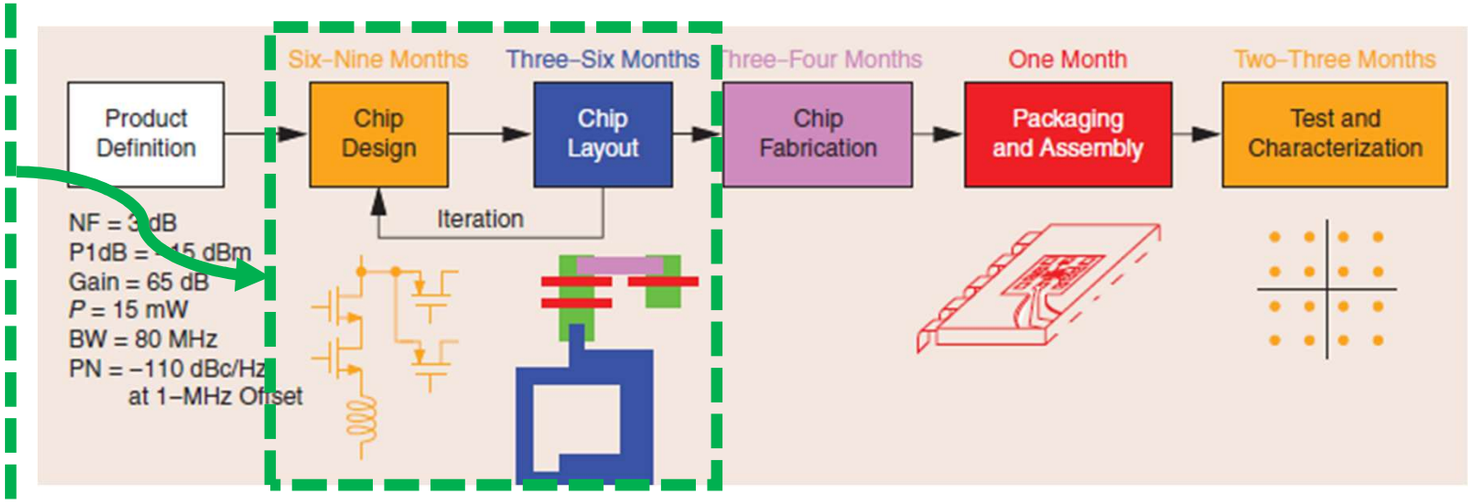


[RAZAVI, IEEE SSCMAG 2024]

Introduction

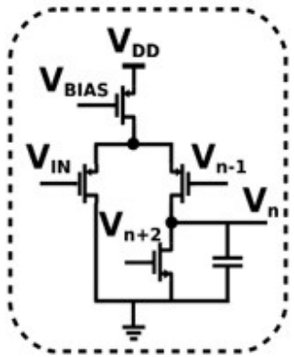
Silicon-proven analog IC design

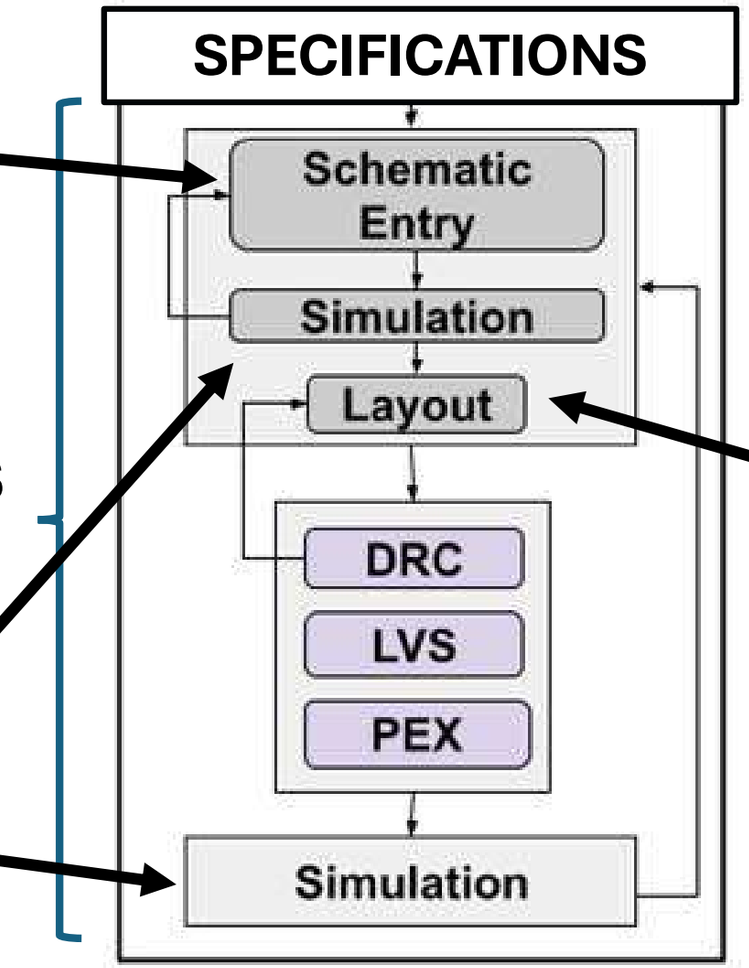




Introduction

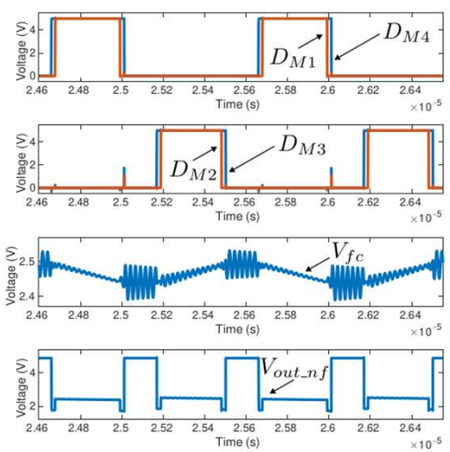
This workshop's plan

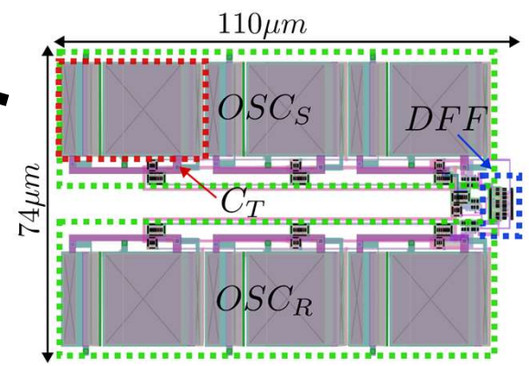




DAYS 2 AND 3

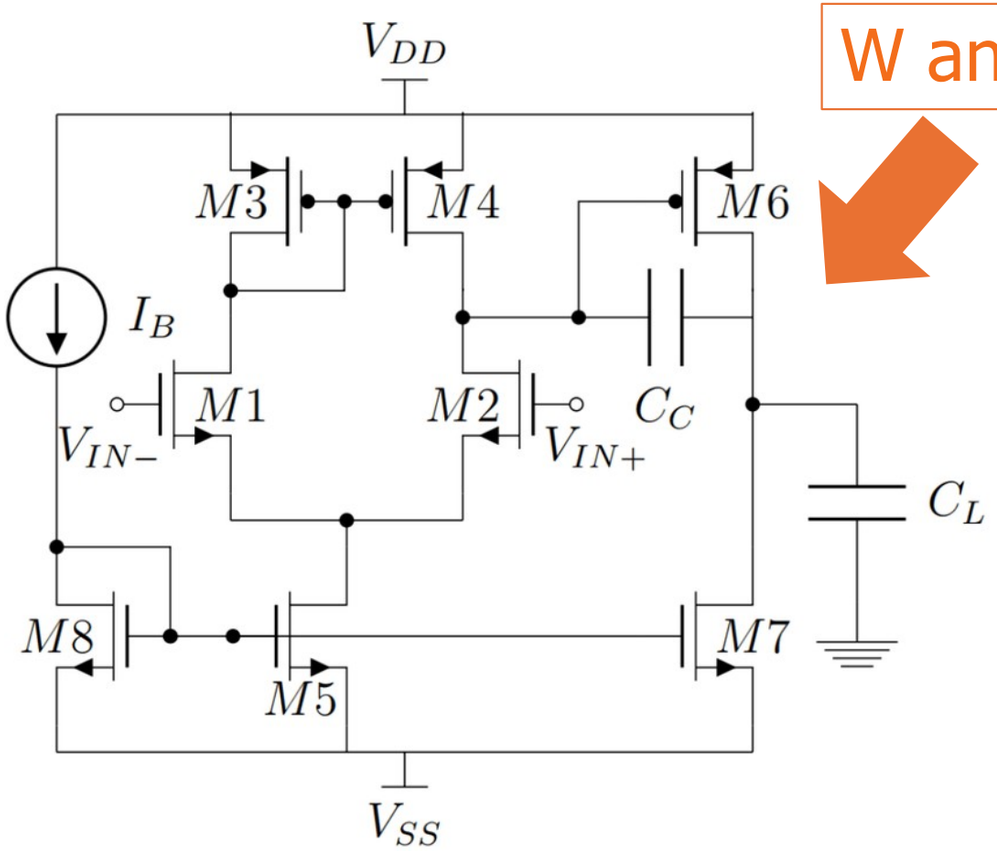
PROJECT (DAYS 4 AND 5)





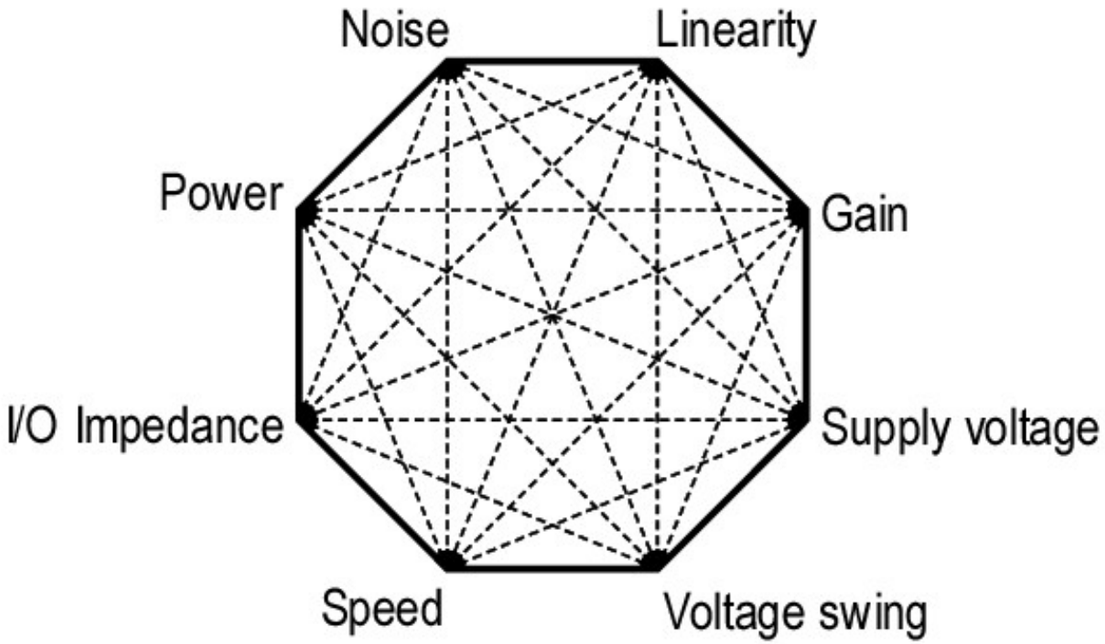
Open-Source Analog Design

Tradeoffs in analog design



Analog block example: Miller OTA

W and L for each transistor M1 to M8?



[B. Razavi]

Performance is limited by the tradeoff in target specifications

Schematic design and simulation

- Relevant tools
  - Xschem → schematic entry and netlist generation
  - Ngspice → simulation based on netlist generated by Xschem

- Visualization
  - Ngspice window → quick checks
  - GAW → integrated in Xschem
  - External viewer through raw data (e.g. Python script)

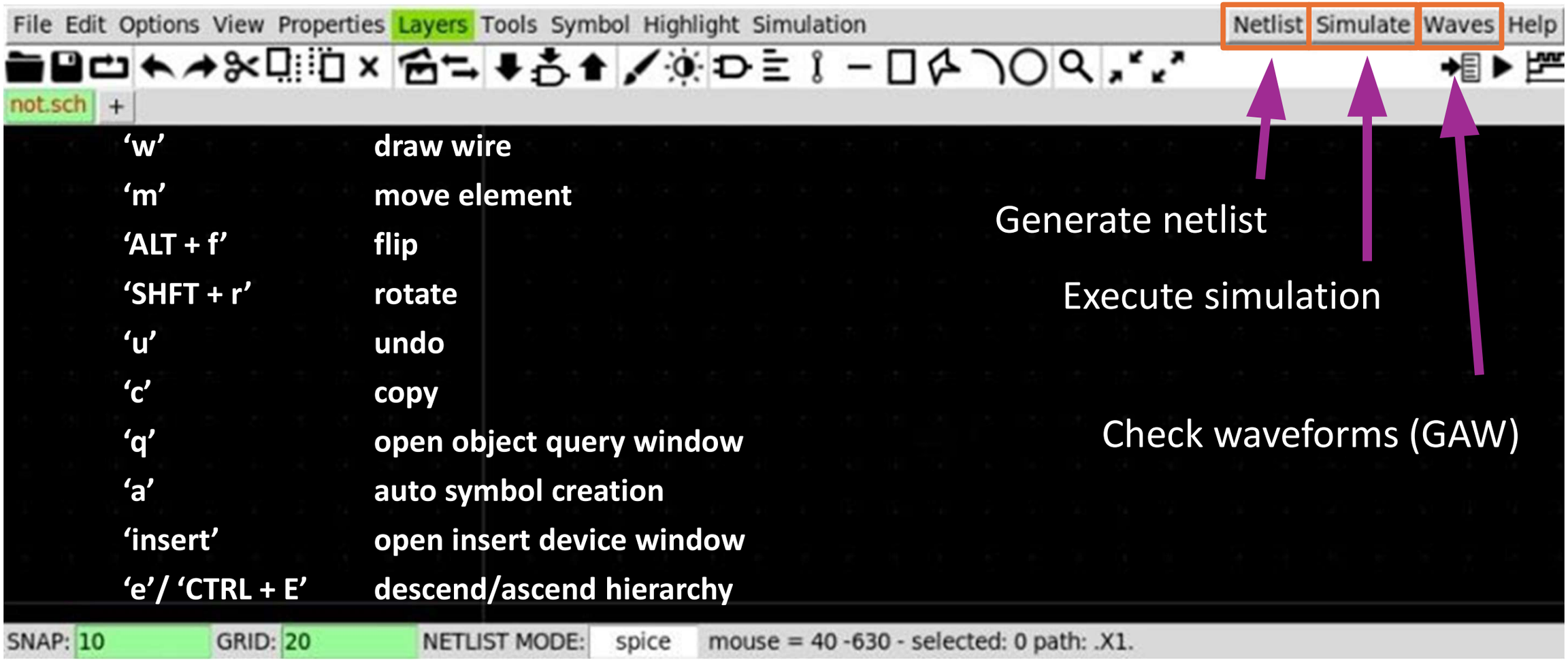
Simulation types

- DC → analysis of the circuit operating point
- Transient → time-domain behaviour
- AC → frequency sweep
- Noise → simulation of device intrinsic noise
- And others…

Ngspice manual will become your best friend!
https://ngspice.sourceforge.io/docs/ngspice-manual.pdf

Xschem GUI basics part 1

www.xschem.sourceforge.io



Simulation scope

- Nominal
  Ideal simulation without considering many fabrication effects
- P(VT) corners
  Considers global process variation (P) and environment (Voltage, temperature, T)

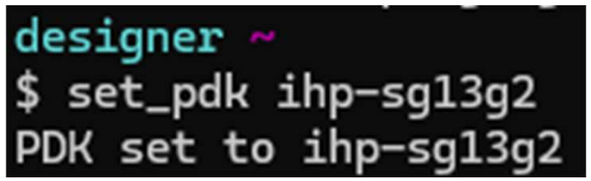
```
.lib cornerMOSlv.lib mos_tt
.lib cornerRES.lib res_typ
.lib cornerCAP.lib cap_typ
```

- Mismatch
  Considers local statistical variation among devices
  → See examples in /opt/pdks/ihp-sg13g2/libs.tech/xschem/sg13g2_tests/mc_*.sch
- Parasitic extraction/ post layout simulations
  Components associated to extrinsic structures (metallization)

Simulation examples

Clone Workshop repo

- Set PDK to IHP 130nm → INSIDE Docker:
  → ls /opt/pdks/ → see installed PDKs
  → set_pdk ihp-sg13g2

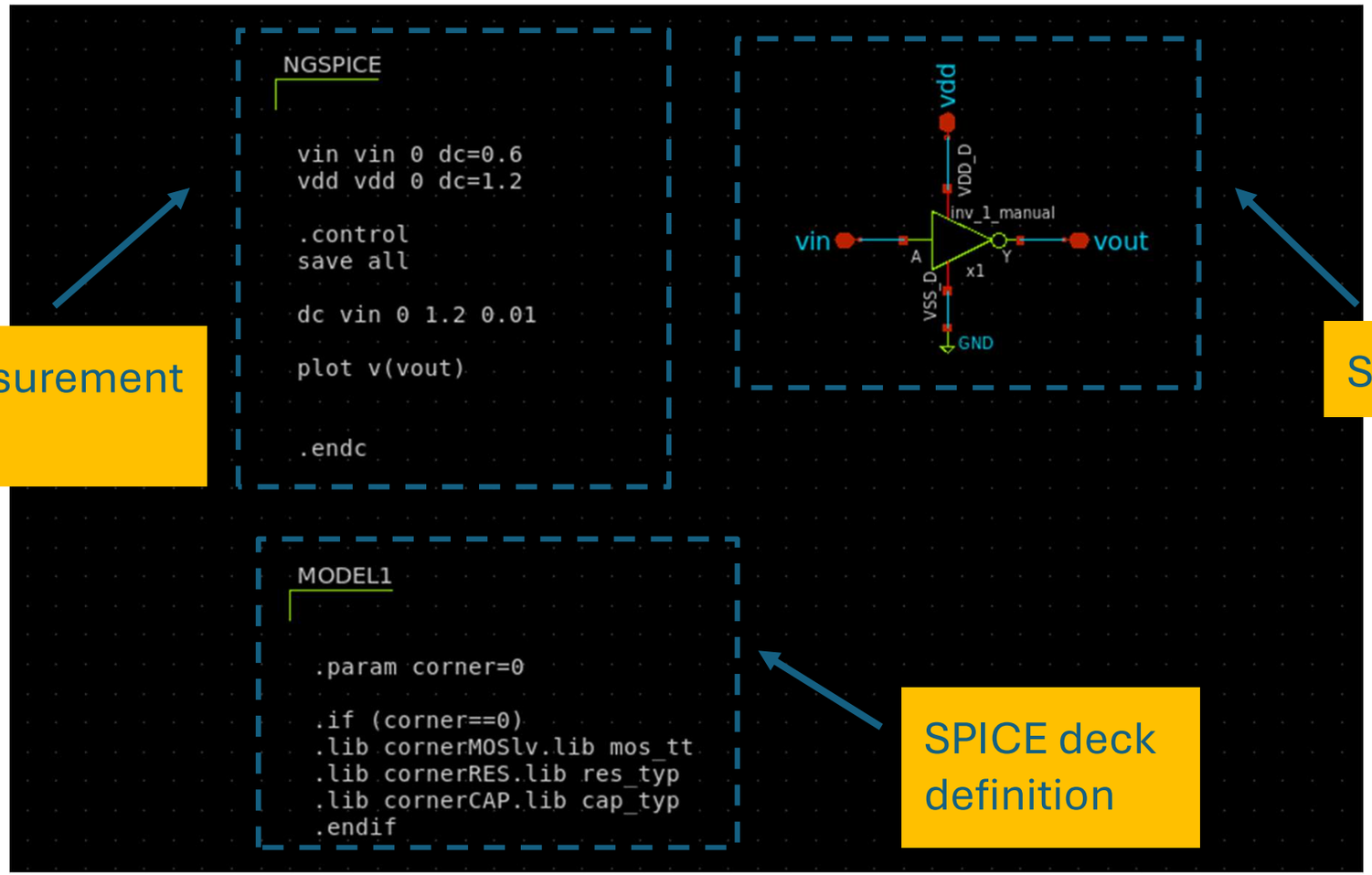


- OUTSIDE Docker:
  → cd [YOUR_INSTALL_FOLDER]\uniccass-icdesign-tools\shared_xserver\
  → git clone https://github.com/JorgeMarinN/OS_AnalogIC_UCU_July2025

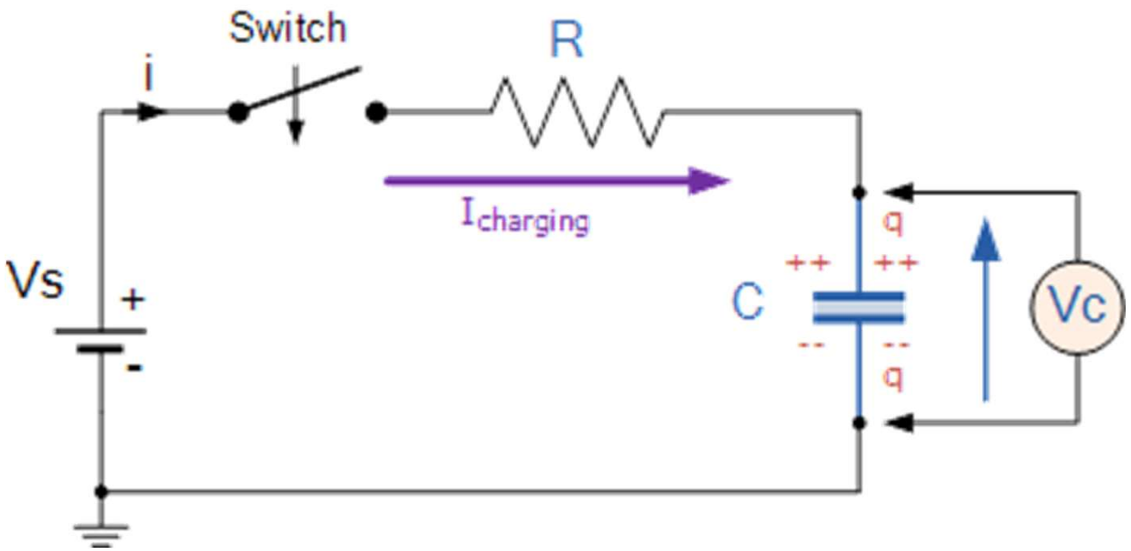
Example #1: Basic inverter

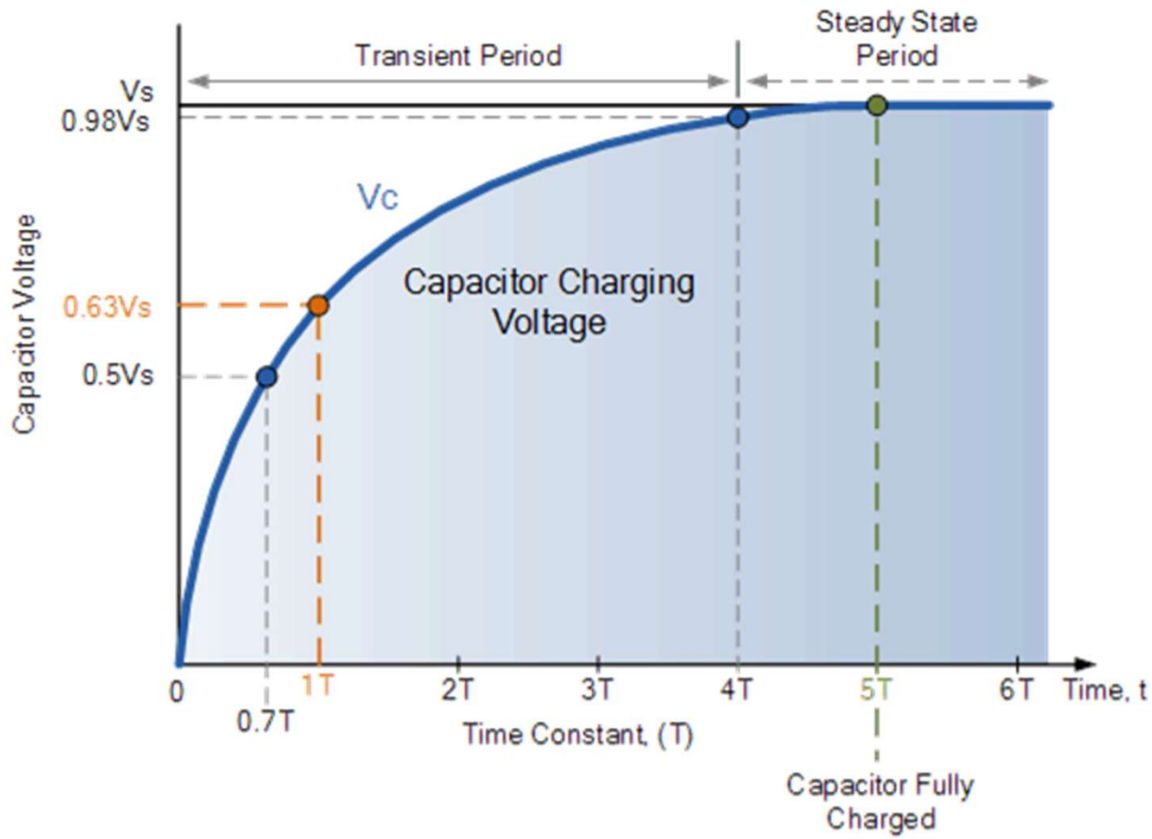
- Github link:

→ https://github.com/JorgeMarinN/OS_AnalogIC_UCU_July2025/blob/main/Day1/tb_inv_1_manual.sch



Example #2: RC constant calculation



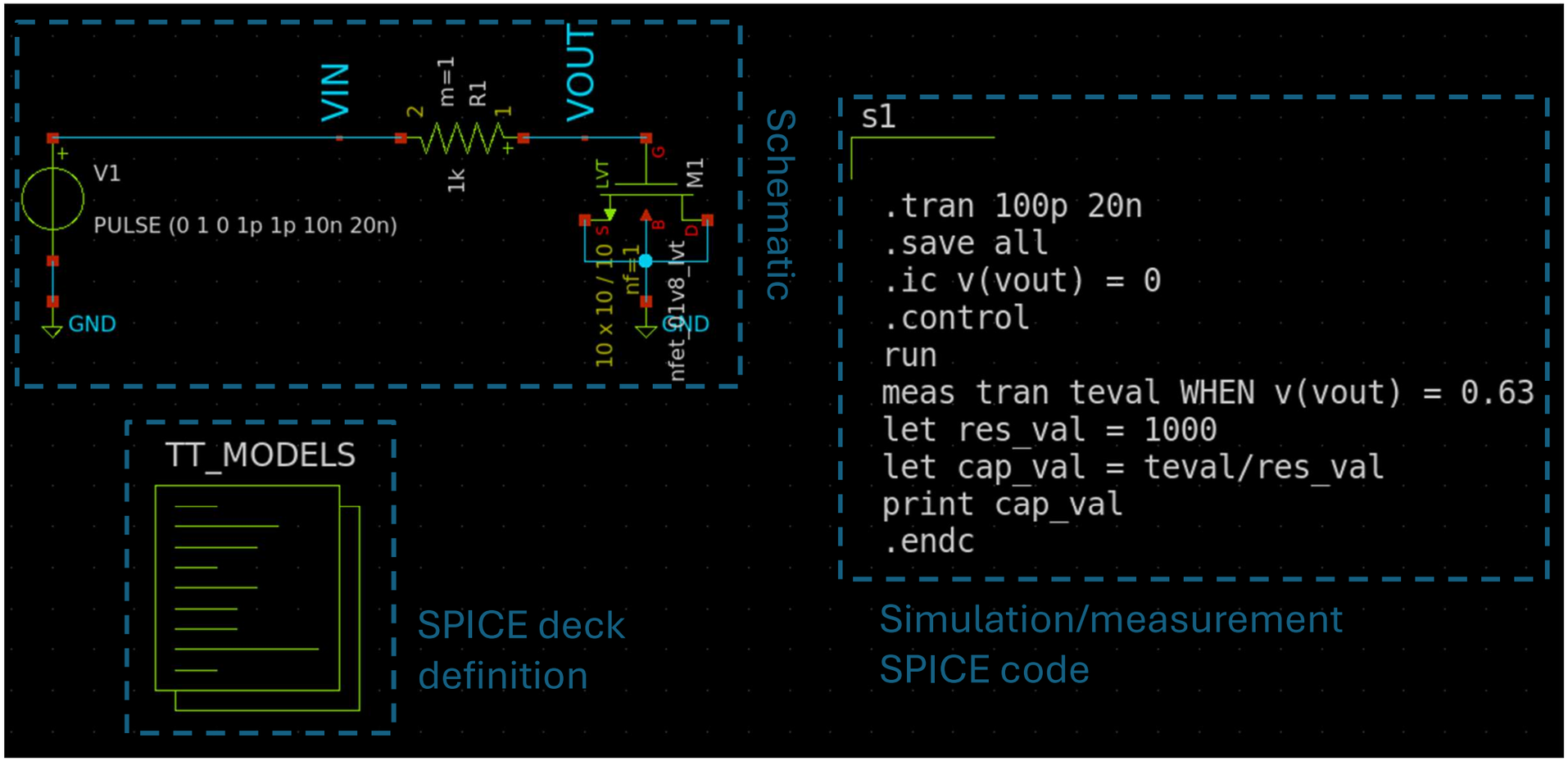


Source: https://www.electronics-tutorials.ws/rc/rc_1.html

Example #2: RC constant calculation

- Github link:

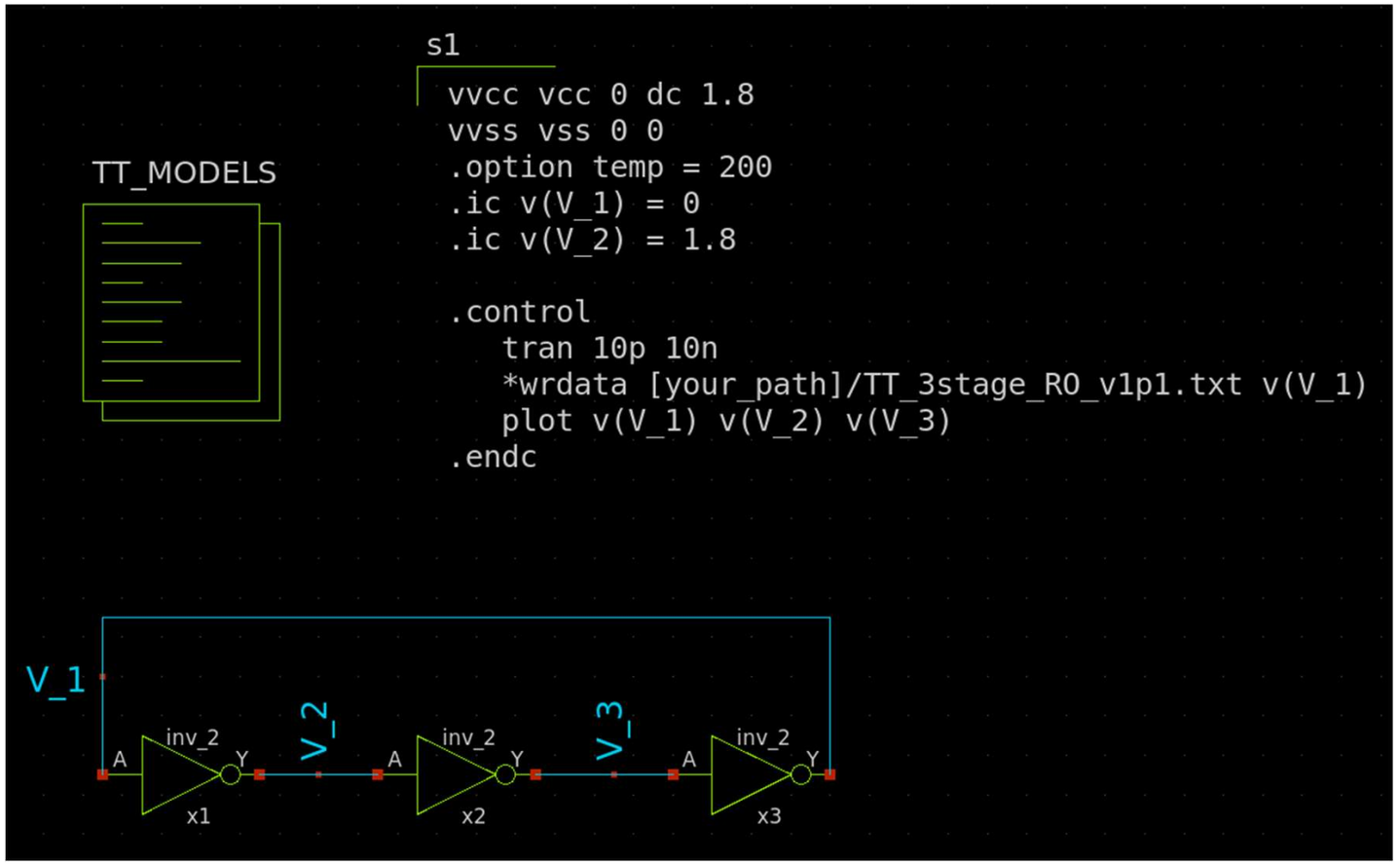
→ https://github.com/JorgeMarinN/OS_AnalogIC_UCU_July2025/blob/main/Day1/rc-ext_circuit.sch
→ https://github.com/JorgeMarinN/OS_AnalogIC_UCU_July2025/blob/main/Day1/cgate-ext_circuit.sch



Example #3: ring oscillator

- Github link:

→https://github.com/JorgeMarinN/OS_AnalogIC_UCU_July2025/blob/main/Day1/tb_3stage_RO.sch



Education using AMS design OS tools

- Traditional IC design flows are not designed for educational purposes
  - The wide variety of tools and workflows can be overwhelming for beginners
  - High costs and restricted PDK availability limit accessibility
  - Limited documentation and minimal community-driven collaboration hinder learning
- Tapeout courses require significant budgets, making them inaccessible to many universities and regions
- IC design environments have traditionally been restrictive
  - Strict NDAs restrict access to essential resources
  - Information sharing is trust-based and highly limited
  - However, this landscape is rapidly evolving, opening new opportunities for education!

Removing barriers: knowledge base

- JKU's "Analog Circuit Design course" → https://github.com/iic-jku/analog-circuit-design
  - Fully-open content for intermediate-level MOSFET circuit design course
  - Based on Xschem and Ngspice examples + IHP technology
  - Uses JKU's IIC-OSIC-TOOLS Docker
- University of Hawai'i's "Analysis and Design of Integrated Circuits" tapeout course → https://github.com/bmurmann/EE628
  - Open content for lectures and assignments
  - Design of a Sigma-delta converter using OS design flow + IHP technology

Removing barriers: knowledge base

- MANY other sources:
  - Carsten Wulff's course: https://youtube.com/playlist?list=PLybHXZ9FyEhbm9-A3QR1NRlt6VxeTXYr5&si=31ccv4rhnWpso_Ci
  - Angel Abusleme's course [in Spanish]: https://youtube.com/playlist?list=PLDYu8HgBbvRFf2PahRmg4ABDxRN60ujKQ&si=jnnEGgbled8ik8av
  - Tiny tapeout: https://tinytapeout.com/specs/analog/
  - [NEW] IHP Analog Academy: https://github.com/IHP-GmbH/IHP-AnalogAcademy

Thank you!
Questions?