

Verilog-AMS in Gnucap

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FOSDEM '26

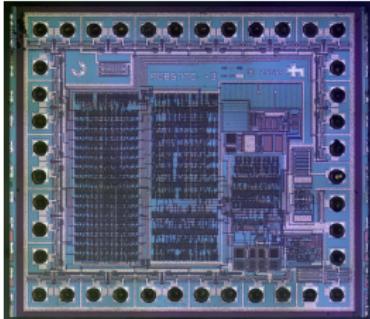
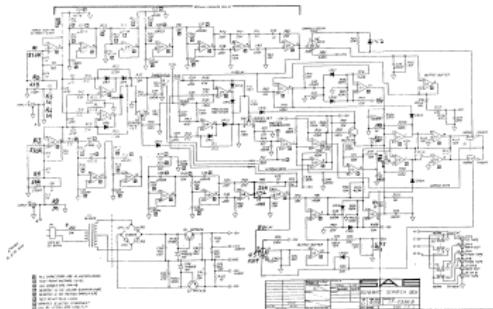


ZERO
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GNU Circuit Analysis Package

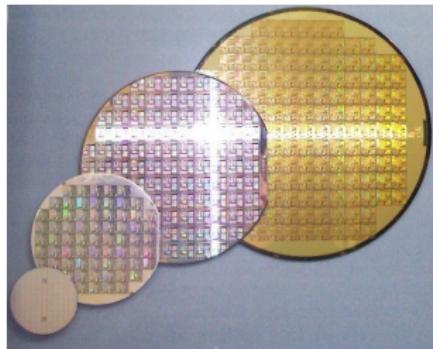
- ▶ Small C++ library for circuit analysis
 - ▶ Plugins (devices, algorithms, languages...)
 - ▶ (Originally) run on hardware too small for SPICE
 - ▶ Pre-Verilog Model compiler, modelgen.
 - ▶ Beyond Spice – mixed techniques for fast analog
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- ▶ 1990. ACS, AI's Circuit Simulator
 - ▶ 2001. *Gnucap*, a GNU project, GPLv3+
 - ▶ 2008–2010. Move to Plugins
 - ▶ from 2022: NLnet funding for Verilog-AMS

Circuits and why?



.. simulate the behaviour

- ▶ often part of the design process.
- ▶ Then somehow make more of them.



images from wikipedia

Why Verilog, IEEE1364 & friends

A standard language for circuit and device modelling

- ▶ “Open Hardware” needs a source language
- ▶ Analog, digital modelling and in between
- ▶ Verilog-95 and “Verilog-A” have become popular
- ▶ Standards define terminology ... and best practice

This one: Widely used in industry

- ▶ IEEE1364: 590 pages, 40 contributors, 12 EDA companies
- ▶ Verilog-AMS: 442 pages, 74 contributors from 16 companies
- ▶ System-Verilog: 586 pages ...

Now trying not to reinvent the wheel

What are plugins again?

- ▶ Dynamically loaded (dlopen) extensions
- ▶ Linux insmod, Python import
- ▶ Stable public interface
- ▶ Decentralised development, no interference
- ▶ Unfinished work available for use/testing/completion.

Some existing examples

- ▶ Input languages: Verilog, SPICE, “Spectre”, gEDA, Qucsator
- ▶ Component models: primitives, modelgen, SPICE, Qucsator
- ▶ Commands: ac, dc, tran, fourier, pz, sparam, postprocessing..
- ▶ Solvers: (C)BS, KLU. Also: node ordering

Your project here.

NLnet funded work & summary

Gnucap Project goals

- ▶ Verilog support in the simulator
- ▶ Model compiler for Verilog-AMS
- ▶ Standardisation and compatibility

Topics for Today:

- ▶ I) File formats for data interchange
- ▶ II) Modelgen-Verilog for Verilog-AMS
- ▶ III) (structural) Verilog support in the simulator
- ▶ IV) (Consistency with) SPICE subsystem
- ▶ V) Revamp data structures & algorithms
- ▶ VI) Testing, QA and work in progress

I a File format for data interchange

Some facts

- ▶ Multiple tools needed to build a chip (or smartphone)
- ▶ Yet another file format with every tool
- ▶ Getting a circuit across can be a pain
- ▶ Most of the time spent validating data exports
(and getting used to wild conventions)
- ▶ Often conversions are one-way only

Example: Circuit Schematics

- ▶ Schematics are circuits with coordinates attached
- ▶ .. and text, and drawings.
- ▶ Verilog syntax permits meta data
- ▶ Always the same circuit, no matter which tool

I b File format for data interchange

Verilog-S, trajectory

- ▶ 2012: S. Krishna: gEDA parser for GnuCap (gsoc)
- ▶ FOSDEM'16: Al's Talk, Proposal for Data Interchange
- ▶ since '23 NLnet funded work on details and spec.
- ▶ '25: `same_port` in GnuCap and `modelgen-verilog`
- ▶ mid '25: Verilog-S support in Qucs (David L.)
- ▶ late '25: improved non-circuit items in `gnucap-geda`

More to do

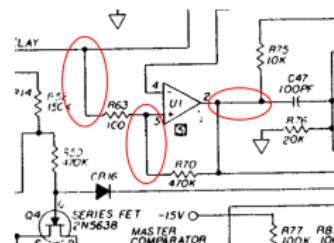
- ▶ Native Verilog-S in Lepton (former gEDA)
- ▶ Looking for a Qucs maintainer/developper
- ▶ Can somebody do xschem, KiCAD please?

Ic File format for data interchange

same_port device?

- ▶ Represent nets (e.g. in Schematics, PCBs, Layout)
- ▶ Nets are first class objects
- ▶ Part of the standard since Verilog-95
- ▶ Available in Icarus-Verilog since .. forever?
- ▶ Unavailable in SPICE tools & friends
- ▶ Perhaps intended in Qucs, now used in schematic files

```
module same_port (.a(i), .b(i));  
  // that's it  
endmodule
```



V Revamp data structures and algorithms

Recent work

- ▶ Shared “commons”, device segmentation
- ▶ Circuit topology (aka union-find)
- ▶ Integration method selection
- ▶ Node ordering: now pluggable
- ▶ Fix parse performance (esp. SPICE)
- ▶ Improved matrix interface (adds: KLU)
- ▶ Event driven simulation (drafted)

V 1 Shared commons and segmentation

On circuit level

- ▶ Device commons: simulation independent data
- ▶ Shared across identical devices (now automatic)
- ▶ Prerequisite for scalability

On behavioural model (compiler) level

- ▶ Identify common structures
- ▶ Identify device state variables
- ▶ Efficient shared storage (now automatic)
- ▶ Prerequisite for mixed & VLSI

V 2 Circuit topology algorithms

Nets

- ▶ may be modelled as shorts, resistors, transmission lines etc.
- ▶ Depends on the application, accuracy requirements etc.
- ▶ `module net (.a(i), .b(i));`
- ▶ Often used in Schematic drawings, Verilog-S..
- ▶ New: Union-find algorithm finds effective nodes
- ▶ Side effect: ground and SPICE style “global” nets

Next steps.

- ▶ Nodes carry disciplines (conservative and signal flow)
- ▶ Automatic partitioning. Catch up on standard compliance.
- ▶ Disciplines determine interconnect models

V 3 Integration method selection

A problem with analog simulation (in a nutshell)

- ▶ Different integration methods, e. g.
- ▶ *Trapezoidal*: nice for smooth signals
allows for large timesteps
but rings after discontinuities
- ▶ *Gear*: nicely damps out ringing
but dissipates energy
- ▶ Each device is different. Need to make choices

- ▶ Per-device method in Gnucap since .. forever
- ▶ Tricks won't work (Has to do with maths)
- ▶ Selection now exposed to the user (Verilog extension)
- ▶ (prereq for large mixed simulations)

VI Testing, QA and work in progress

- ▶ Continuous Integration @ codeberg
- ▶ Populate models repo with devices and tests
- ▶ Numerical cross validation
- ▶ Generic testbenches for semiconductor models
- ▶ OSDI wrapper
- ▶ IHP PDK, Verilog-AMS port

VI 0 Continuous Integration

Thanks to Eric @ CCT

- ▶ CI runner set up on Codeberg
- ▶ “Modernise” official contribution process
- ▶ Repo structure needs work
- ▶ (Need contributors, still).

VI 1 Models and validation

gnucap-models repo: device collections for Gnucap

- ▶ from Spice3f5, jspice3-25 (historic, unmodified)
- ▶ ngspice-17 .. current
- ▶ devices from berkeley (bsim3, 4)
- ▶ psp, bsim4va, rram, .. (Verilog, WIP)

Purpose:

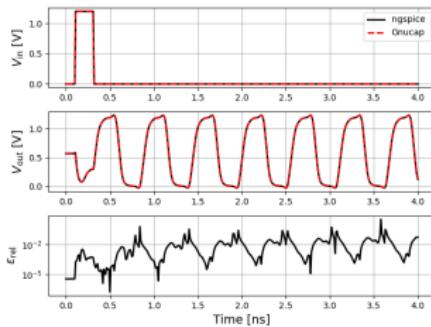
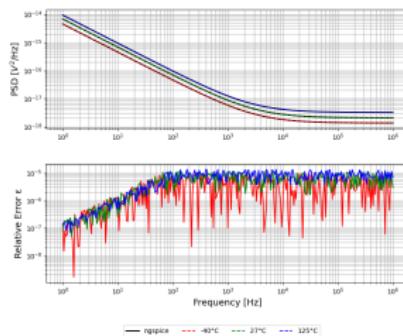
- ▶ Archeology – what did you get in 1990?
- ▶ Regression testing against reference figures
- ▶ Validation (models and new solvers)
- ▶ Find bugs (ngSpice: 1, modelgen: 2.)

VI 2 Numerical cross validation

Thanks to Lukas D & NLnet

- ▶ Comparison against other FOSS tools

MOSFET + resistor noise at different temperatures



- ▶ Goal: standard test procedures that work with known simulators.
- ▶ Method: Verilog-S, map-to-application.
- ▶ Separate NLnet funded project intended

VI 3 OSDI wrapper (OpenVAF)

OpenVAF: another model compiler

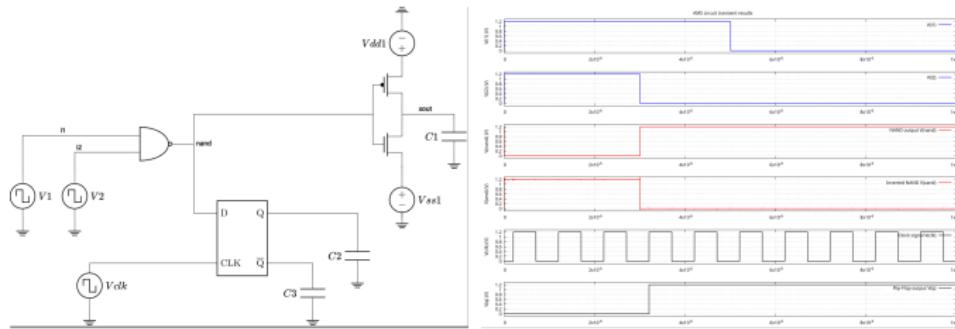
- ▶ Pretty fast compilation.
- ▶ Obviously big (“compact”) models
- ▶ Basically, SPICE subset of “Verilog-A”
- ▶ Very popular in analog simulation

Use OSDI in Gnucap (Lukas, WIP)

- ▶ Devices are plugins, use one or the other
- ▶ Mechanism modelled after spice-wrapper
- ▶ All features combined in one framework

VI 4 IHP PDK Verilog-AMS port

- ▶ Work in progress with Krzysztof @ IHP
- ▶ Initiative: Pepijn D (IHP/#725)



- ▶ Semiconductor device library
- ▶ Mixed signal cell library
- ▶ Statistical modelling, mismatch analysis
- ▶ Towards official support for Gnucap

Thanks

Get started

- ▶ Wiki <http://gnucap.org>
- ▶ Mailing list gnucap-devel@gnu.org
- ▶ Chat [#gnucap:matrix.org](https://matrix.org/#gnucap)

More work to do

- ▶ Plugins, wrappers, extensions
- ▶ Data exchange, standard compliant tools
- ▶ Funding (still) available