# Gnucap – Architecture, Algorithms and Applications

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# Gnucap – Architecture, Algorithms and Applications

- About Gnucap & motivation
- Aims and objectives
  - discrete & continous models
- Algorithms
- Architecture aspects
  - what makes Gnucap
- Applications
  - gnucap-python
  - QUCS & gnucsator
- Attempt to clarify license issues

# About Gnucap & motivation

History

- 1983. First traces (Albert Davis)

..

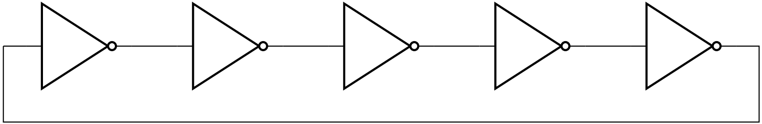
- 2017. Current stable release 20171003.

Motivation

- replace Spice, the old approach
- better, faster algorithms
- mixed signal simulation (now verilog-AMS)
- ongoing research

# Aims & Objectives, some Basics

- digital circuit recap

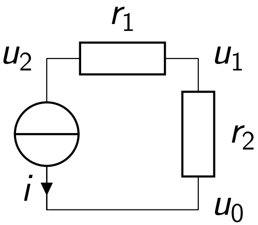


- discrete voltages
- discrete time, *event queue*
- evaluate event, create new ones, then
- advance time to next event etc.

# Aims & Objectives, some Basics

- analogue circuit
  net with conductances and controlled sources
- operating point and transients:
  similar problems, look at the former.

# From circuit to matrix




- conductances and current sources are known
- currents into a net sum to zero. let $g = 1/r$
- top right $(u_1 - u_2) \cdot g_1 - (u_2 - u_0) \cdot g_2 = 0$
- top left $(u_1 - u_2) \cdot g_1 - i = 0$ etc.
- $$\begin{pmatrix} g_2 & -g_2 & 0 \\ -g_2 & g_2 + g_1 & -g_1 \\ 0 & -g_1 & g_1 \end{pmatrix} \begin{pmatrix} u_0 \\ u_1 \\ u_2 \end{pmatrix} = \begin{pmatrix} i \\ -i \\ 0 \end{pmatrix}$$

# Analog circuit, some facts

- $$\begin{pmatrix} g_2 & -g_2 & 0 \\ -g_2 & g_2+g_1 & -g_1 \\ 0 & -g_1 & g_1 \end{pmatrix} \begin{pmatrix} u_0 \\ u_1 \\ u_2 \end{pmatrix} - \begin{pmatrix} i \\ -i \\ 0 \end{pmatrix} = 0, \text{ easy}$$
- more common: $g$ and $i$ depends on $u$
  $$F(u) = M(u) \cdot \begin{pmatrix} u_0 \\ u_1 \\ u_2 \end{pmatrix} - \begin{pmatrix} i_0(u) \\ i_1(u) \\ i_2(u) \end{pmatrix} = 0$$
- need $u$ sth $F(0) = 0$
- compute $M(u), y(u)$ and $M(u)^{-1}y(u)$
  for many $u$ ("Newton iteration")
- quite expensive operations

# Algorithms, bypassing

- event queue $\rightsquigarrow$ evaluation queue
- Gnucap keeps track of voltage changes.
- $M(u), y(u)$, model evaluation *as needed*
- $M(u)$, filling in the matrix *as needed*
- Inversion more difficult.
- $M^{-1}$ is never computed,
  decompose $M = L \cdot U$ instead
- But only update $L$ & $U$ where $M$ has changed
- Tons of overhead, gain is even higher
  (without loss in accuracy)

# Algorithms – remarks

- More bypassing is possible. Not implemented
- Swapping $n_1$ and $n_2$ affects the nonzero pattern
$$\begin{pmatrix} * & * & 0 \\ * & * & * \\ 0 & * & * \end{pmatrix} \Leftrightarrow \begin{pmatrix} * & 0 & * \\ 0 & * & * \\ * & * & * \end{pmatrix}$$
- The node ordering determines the storage
- which affects LU decomposition
- Finding a good node ordering is hard.
- the (related) *bandwidth problem* is NP-hard.

# Architecture – why bother?

- the parts that will not easily change
- Conceptual integrity, reflect the vision of the architect.
- It's hard to get all of
  - stability
  - scalability
  - maintainibility
  - extensibility
- Verilog-AMS, VHDL, SystemC/AMS considered
- Only few unsettled parts

# Architecture – library and plugins

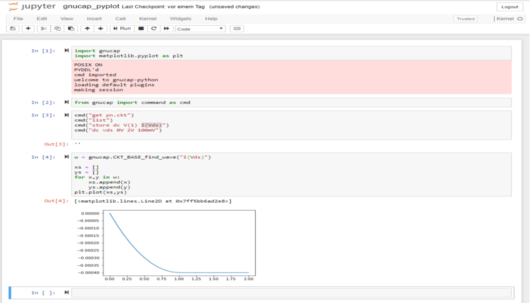
- Shared library
  - objective approach (subset of C++)
  - base classes for the replaceable parts
  - POSIX (but portable)
  - generic relation pattern
  - ..
  - application independent, minimal
- Everything else: plugins (dlopen)
  - components
  - commands, algorithms
  - ..
  - room for contributions and WIP
  - unsupervised but controlled growth

# Architecture – plugin benefits

- easy development & deployment
- Touring completeness
- (usually) no forking required
- success stories
  - `>>> import module` (python)
  - `# insmod module` (linux)
- new ideas (customisation, gnucap-custom)

# Applications: gnucap-python

- use Gnucap in a Python program[1]
  do plotting or parameter optimisation etc.
- Gnucap in a Python/Jupyter notebook[2]




- readily available in Debian, Arch (AUR)
- the usual python wrapping
- but not *just* that

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[1] Henriks idea

[2] kindly provided by Patrick

# more gnucap-python

- implement components in Python
  - suited for testbenching
  - custom probes, logic analyser etc.
  - arbitrary data sources in simulations
- implement commands in Python
  - access internal data (`numpy`)
  - combine with other Python libraries
  - e. g. SPICE-like `.pz` command, calling `scipy.linalg.eig()`
- the implementation
  - SWIG and some tweaks
  - share a symbol space
  - maximise hackability

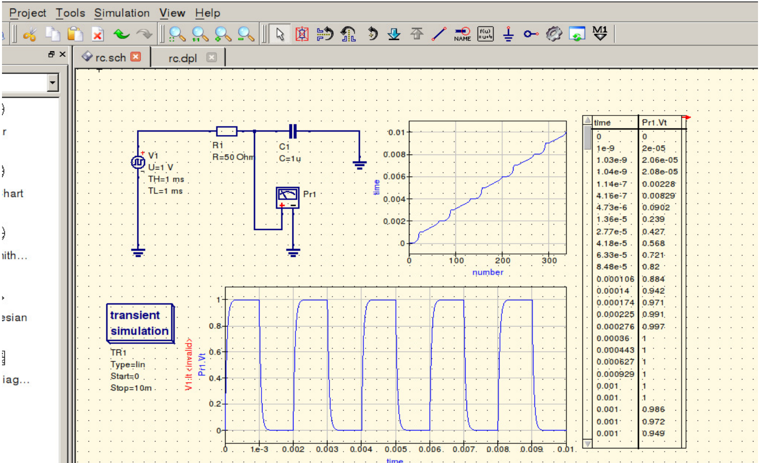
# Application in QUCS

- graphical schematic capture
- displays simulation results
- uses qucsator circuit simulator
  custom netlist format
- (Qt5 port pending)

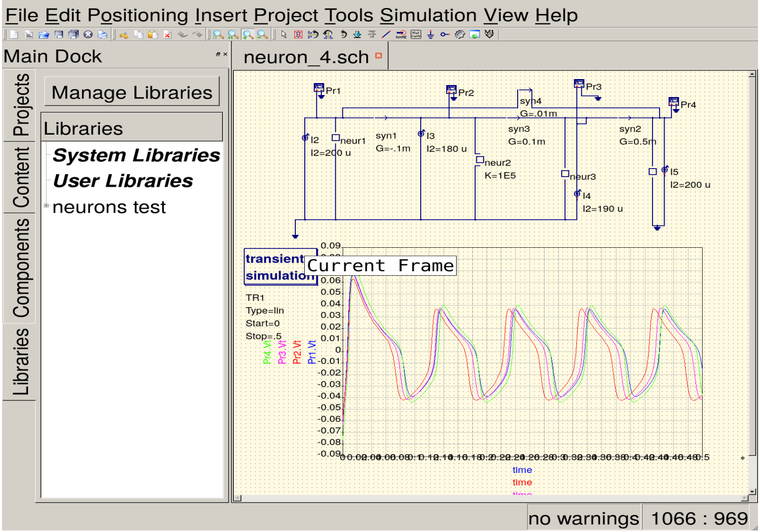
# Application in QUCS

- gnucsator: a few plugins to
- read qucsator format
- and produce qucsator output.
- relevant components in a library

```
$ QUCSATOR=gnucsator.sh qucs -i rc.sch
```



# QUCS/gnucsator and Verilog-A



# Model license considerations

- Support for models from other projects
  (not all projects are GPLv3+)
- 1. Models distributed as source code
  - `gnucap> load_va neuron.va`
    (no issue whatsoever)
- 2. Models distributed as binary blob
  - now need model blob and wrapper
  - model distribution is legal, if it's yours
    (and no copyleft code involved)
  - wrapper binary might not be distributable
    (just compile as needed)
  - see examples in gnucap-models
    not all those models are free

# Summary

- faster algorithms by thinking mixed mode
- Gnucap provides the space for improvement
- more frontend work is on the way
- model licenses are not an issue

Thank You.