Zero: yet another a modern circuit simulation tool

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GWADW, Elba, 2019-05-23
LISO

• “Linear Simulation and Optimization of analog electronic circuits”

• Developed by Gerhard Heinzel in the mid 90s

• Motivated by:
  - Unrealistic op-amp behaviour found in SPICE
  - Need to determine stability criteria in circuits
  - Need for a fitting/optimisation tool

• C based, closed source

• Performs linear analysis, a la Finesse, Optickle, etc.

• Circuit and analysis defined via input file
What people use LISO for

• **Response calculations**
  - Send signal in, read signal out at various nodes or components

• **Noise calculations**
  - Calculate noise at a node or component from other nodes/components

• **Optimisation and fitting**
  - Find appropriate component values that yield predetermined response functions

• **Stability analyses**
LISO limitations

- LISO has worked pretty well for 20 years!
- But there are some limitations:
  - Closed source; available only via email; officially Linux only
  - Everything goes through input and output files; harder to run parameter studies / batch jobs (same problems as Finesse ≤2)
  - Cannot fit noise, only responses
  - Everyone has their own version of the op-amp library
Zero

• A clone of parts of LISO into a more accessible form to facilitate new features
• Python-based, open source
  – Cross-platform
  – Can use in Jupyter notebooks
  – Access to large scientific Python ecosystem (NumPy, SciPy, control systems toolbox, Finesse 3, etc.)
  – Modular; can bolt-on new analyses or use different solvers in future
• Supports most LISO input syntax (circuit mode) but also native Python
• Includes expanded LISO op-amp library (YAML formatted)

In [1]: from zero.liso import LisoInputParser
   import matplotlib.pyplot as plt

In [10]: # Init parser.
   parser = LisoInputParser()
   # Parse LISO script.
   parser.parse(""
   # Sallen-Key filter
   r r1 400k nin n1
   r r2 400k n1 n2
   r r3 50 n5 n3
   r rs 230 n5 n6
   r led 48.6 n6 gnd
   c c1 20u n1 n3
   c c2 10u n2 gnd
   op op1 op27 n2 n3 n4
   op op2 buf634 n4 n5 n5
   freq log 3m 300 1000

   uinput nin 0
   noise n6 sum
   noisy all ""
   ")

In [11]: # Simulate circuit.
   solution = parser.solution()

In [12]: # Show results.
   solution.plot()
   solution.show()
Command line interface

- **Show and save simulation results/plots**
  - `zero liso my-circuit.fil --save-figure circ.pdf`

- **Search op-amp library with binary operators**
  - `zero library search "vnoise < 3n & inoise < 1p"`

- **Automatically download op-amp datasheets using search query**
  - `zero datasheet -f "OP27"`

- **Print circuit matrix / equations**
  - `zero liso my-circuit.fil --print-matrix --print-equations`

- **Open library and config in text editor**
  - `zero config --help`
Prettier plotting

- Export in any format supported by Matplotlib
- Plot multiple formats at the same time
Simulation results

- Results as queryable objects and not just text files
  - Functions know their units, can check if units clash when performing mathematical operations*

- Easily combine results from multiple simulations in single plots, then plot together
  - \text{solution}_c = \text{solution}_a + \text{solution}_b

*Currently separate project (https://git.ligo.org/sean-leavey/freqstab/), will be merged soon
Comparing to LISO

- **LISO files in Zero can be compared to LISO automatically**
  - `zero liso my-circuit.fil --compare`
  - Runs LISO directly and overlays results to Zero

- **Automatic tests against hundreds of LISO files identical within $10^{-5}$ relative/absolute tolerance**
Zero as part of wider analyses

- AEI 10 m reference cavity open loop gain model
  - Zero
  - Finesse
  - Python control library

https://git.ligo.org/sean-leavey/freqstab/
Limitations of Zero

• No direct fitting and optimisation functionality
  – But Zero can be included as a library within other fitting and optimisation tools

• Stability, max input, etc. analyses not yet available (but can be added if there is a desire)

• Slower (currently)
  – But could be improved with C-based sparse matrix solver a la Finesse 3
Future

- Continue to expand op-amp library
- Support realistic passive components (resistors with stray C, L, excess noise, etc.)
- Support arbitrary op-amp noise, not just 1/f
- Future direction depends on feedback from you!
Where to get it

- **On your computer**
  - pip install zero

- **On GitLab**
  - https://git.ligo.org/sean-leavey/zero

- **Help and support**
  - Examples on GitLab
  - Documentation at https://docs.ligo.org/sean-leavey/zero/
  - GitLab issue tracker for help/requests/complaints
  - Circuit simulation Mattermost channel: https://chat.ligo.org/ligo/channels/circuit-simulation
Thanks for listening!
New features in Zero

- **LISO syntax parser**
  - Helpful syntax error messages
  - Easy to extend LISO syntax in the future
  - Adapted into Finesse 3