Getting started with the new PSpice® for TI design and simulation tool

Ian Williams

APP – LP – LDO
About me – Ian Williams
Business lead, Low-Voltage LDOs

• Career
  – BSEE University of Texas at Dallas, 2009
  – TI since 2009, LDO since July 2020

• Expertise
  – 11 years working with various types of amplifiers
  – Co-creator of GWL amplifier SPICE model architecture
  – Co-creator of TI Precision Labs – Op Amps

• Fun fact
  – Big music guy – have performed at festivals, DJ’d at clubs and on FM radio, and even met my wife at Coachella 2013
Agenda

• TI simulation tools overview – 10 min.
• PSpice® for TI deep dive – 10 min.
  – Features and limitations
  – Built-in model library
• Setup and simulation examples – 25 min.
  – Operational amplifier: OPA211
  – Power supply: TPS7A52
  – Modeling Application: Power MOSFET
• Additional resources

Please ask your questions in the chat!
Part 1
TI simulation tools overview

Tip: SPICE stands for “Simulation Program with Integrated Circuit Emphasis”
Time for some audience participation…

What is your experience level with SPICE simulation?

- 0: Can't spell SPICE
- 0: Ran sims once or twice
- 0: Know enough to be dangerous
- 0: SPICE savvy
- 0: SPICE guru
Introducing PSpice® for TI

PSpice for TI will help engineers speed time to market and reduce development costs, delivering:

• Full-featured simulation of entire systems.
  – Advanced capabilities, including Monte Carlo and worst-case analysis.
  – Synchronized library of >5,700 models and counting.
  – No design size limitations.
  – Easy transition to layout and prototype.

• Integrated design resources.
  – Quick access to TI product information.
  – No need to manually upload new TI models.
Why is TI partnering with Cadence?

**Growing demand**
There is an increased need for simulation software to test new design concepts, accelerate product development and demonstrate regulatory compliance.

*Source: ABI Research*

**Short design timelines**
Today’s design engineers must produce accurate designs on tight deadlines — in many cases, reducing the prototyping and evaluation phases of their designs.

**Desire for more advanced simulation**
Existing simulation tools in the market lack advanced analysis capabilities, model portability and flexibility, and easy library synchronization.

“Tools that are intuitive and include system-level simulation capabilities can cut the development time and speed time to market.” – Kevin Anderson, Omdia
### Fundamentals & skill-building
- Educational e-books
- **Technical articles**
- **TI Precision Labs**
- **Power Supply Design Seminars (PSDS)**
- Additional videos at [training.ti.com](http://training.ti.com)

### Investigation & brainstorming
- Easy part selection on TI.com
- **Reference designs** for specific applications
- Application notes and technical white papers

### Design & simulation
- Evaluation modules
- **WEBENCH® Power Designer**
- **Filter Design Tool**
- **Analog Engineer's Calculator, Circuit Cookbooks & Pocket Reference**
- **TINA-TI™**

### Design support
- [e2e.ti.com](http://e2e.ti.com)
- Forums for expert answers to technical questions

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**Is PSpice for TI replacing other TI tools?**
## PSpice for TI vs. TINA-TI

<table>
<thead>
<tr>
<th>Analysis / simulation</th>
<th>PSpice for TI</th>
<th>TINA-TI</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC, Noise, BIAS point, DC sweep, Transient, Fourier</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Variable sweeps</td>
<td>Temperature, component, parametric</td>
<td>Temperature, component</td>
</tr>
<tr>
<td>Monte Carlo analysis</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Worst case analysis</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Libraries / components</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal libraries</td>
<td>~5700</td>
<td>~1300</td>
</tr>
<tr>
<td>Automatic library updates</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Built-in modeling application</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Schematics</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Create hierarchical schematic</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Multipage schematics</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Part 2
PSpice for TI deep dive

Tip: PSpice for TI runs offline!
Software features and limitations FAQ

Q. Does PSpice for TI work offline?
   A. Yes, an internet connection is not required to run.

Q. Is there a maximum number of nodes?
   A. No, there are no design size limitations. You can also use multi-page schematics and hierarchical blocks.

Q. Are there any other limits to be aware of?
   A. Yes. The tool is designed primarily as a SPICE simulation environment for use with the built-in TI models. If third-party models are imported, then only three nodes can be probed simultaneously.
Built-in TI model library

Includes device-specific test benches
To accelerate your development

Matches the product tree on TI.com
How do I update the TI model library?

• Updates to the model library are automatically detected and performed at software startup.
  – The user can choose not to update.
• The model library is installed locally on the user’s hard drive. Models can be copied and imported into other tools if desired.
  – Location: C:\SPB_Data\cdssetup\pspTILibDir
Are models editable?

• Models are text files and may be edited with a text editor (I recommend Notepad++) from the library directory.
  
  – **Note:** editing TI models breaks their signature, causing the tool to treat them as 3rd-party.

• Some models have user-editable parameters. Editing these **does not** break signature.

• If you edit a model and save it in the same location, it will get over-written during the next library update.

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**Model file example**

```plaintext
Model file example
```

**Texas Instruments**

14
Modeling application

- Used to add customizable, parameterized components to your design:
  - Power MOSFETs
  - Power diodes
  - Passives with parasitics
  - Independent sources
  - Switches
  - Transformers
- Click Place → PSpice Component… → Modeling Application in the top menu bar
- **Note:** these components do not trigger the probe limit
Modeling application, cont.

• A simple UI opens for each type of component with editable fields
• Customize each parameter to your liking, then click \textit{Place} to drop in schematic
  
  \textbf{Note:} Device parameters can still be edited from their properties once in the schematic

\begin{itemize}
  \item Power MOSFET window
  \item Power NMOS in schematic
\end{itemize}
Additional included model libraries

• These standard PSpice libraries are also included:

<table>
<thead>
<tr>
<th>Library</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABM</td>
<td>Analog behavioral models for various math functions</td>
</tr>
<tr>
<td>ANALOG</td>
<td>Passives, dependent sources, switches, transmission lines</td>
</tr>
<tr>
<td>BREAKOUT</td>
<td>Customizable versions of many device types</td>
</tr>
<tr>
<td>DIG_MISC</td>
<td>Digital timing control, pull-up / pull-down resistors</td>
</tr>
<tr>
<td>DIG_PRIM</td>
<td>Logic gates, flip-flops</td>
</tr>
<tr>
<td>SOURCE</td>
<td>Independent voltage and current sources</td>
</tr>
<tr>
<td>SPECIAL</td>
<td>Parameters, simulation control, library management, utilities</td>
</tr>
</tbody>
</table>

• **Note:** components from these libraries *do not* trigger the probe limit
Importing third-party or custom models

• With your **project** (.opj) selected, click **Tools → Generate Part**
• Browse to your model file in the new window, make your selections, and click **OK**
• The new model appears in your project’s library
# Types of models on TI.com

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PSpice</strong></td>
<td>Analog / mixed-signal model for use in PSpice-based simulators. Packaged in a way to be easy to import and use in PSpice / Cadence / OrCAD.</td>
</tr>
<tr>
<td><strong>TINA-TI</strong></td>
<td>Analog / mixed-signal model for use in PSpice-based simulators. Packaged in a way to be easy to import and use in TINA-TI.</td>
</tr>
<tr>
<td><strong>HSPICE</strong></td>
<td>Analog / mixed-signal model for use in HSPICE-based simulators. HSPICE is a branch of SPICE similar to PSpice, but models are not directly compatible.</td>
</tr>
<tr>
<td><strong>SIMPLIS</strong></td>
<td>Switch-mode power supply model for use in SIMPLIS.</td>
</tr>
<tr>
<td><strong>IBIS</strong></td>
<td>I/O Buffer Information Specification model, typically used for digital pin timing analysis. Compatible with a broad range of industry simulators.</td>
</tr>
</tbody>
</table>
Part 3
Setup and simulation examples

**Tip:** Enabling AutoConverge in your sim profile can fix a broad range of convergence issues.
Operational amplifier example – OPA211

Schematic capture

AC simulation result
Power supply example – TPS7A52

Schematic capture

Transient simulation result
Modeling Application – Power MOSFET

Schematic capture

DC simulation result
Tip: Choose the “Last Plot” setting in your sim profile to preserve results display settings between runs.
Additional resources

**Hands-on training manual**

- Self-guided, step-by-step tutorial that walks the user through the entire tool workflow
  - Includes basic and more advanced content
  - Includes debugging and troubleshooting
- Available from the PSpice for TI start page:
  - Click *Training Course*
Additional resources, cont.

Overview content

- How to simulate complex analog power and signal-chain circuits with PSpice® for TI
  
  [Link]

- PSpice for TI overview video
  
  [Link]

Technical training videos

- [Link]

TI.com/pspice-for-ti
“Trust, but verify” SPICE models

• Series of articles that covers verifying parameters of amplifier models:
  – Part 1: Output impedance
  – Part 2: Small-signal bandwidth
  – Part 3: Input-referred errors
  – Part 4: Noise
Direct support from TI

• For tool-related support: Simulation, hardware & system design tools forum
• For specific model or product support: post to that product’s forum
  – i.e. For amplifier support, post to the Amplifiers forum

Note: these forums are all supported by TI applications engineers who are graded on responsiveness and quality of support. You should get an initial reply in 24h.
## SPICE tips – analysis parameters

<table>
<thead>
<tr>
<th>Option</th>
<th>Default</th>
<th>Relaxed</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>AutoConverge</td>
<td>Off</td>
<td>On</td>
<td>Relaxes multiple parameters if needed to enable convergence</td>
</tr>
<tr>
<td>ABSTOL</td>
<td>1e-12</td>
<td>1e-10</td>
<td>Sets the absolute tolerance of nodal currents between DC iterations</td>
</tr>
<tr>
<td>RELTOL</td>
<td>1e-3</td>
<td>3e-3</td>
<td>Sets the relative tolerance of the nodal voltages at each DC iteration compared to the first</td>
</tr>
<tr>
<td>GMIN</td>
<td>1e-12</td>
<td>1e-10</td>
<td>Adds conductance parallel to every p-n junction</td>
</tr>
<tr>
<td>CSHUNT</td>
<td>0</td>
<td>1e-15</td>
<td>Adds capacitance from every node to ground</td>
</tr>
</tbody>
</table>
SPICE tips – DC path to GND

• Ensure DC path to ground at every node
  – Can force a path with large resistors (1T, etc.) that don’t affect electrical performance
  – Try to use the smallest value possible
SPICE tips – linear circuits

• Design functional blocks with as linear behavior as possible
  – Sharp transitions or discontinuities cause issues with convergence checks
  – Use R-C filter networks to reduce bandwidth of subcircuits for smooth transitions
  – Use voltage inputs and current outputs wherever possible

Voltage inputs
Current output
R-C filter slows edges of subcircuit output
Resistor converts current to voltage and provides DC path to GND

- Design functional blocks with as linear behavior as possible
- Sharp transitions or discontinuities cause issues with convergence checks
- Use R-C filter networks to reduce bandwidth of subcircuits for smooth transitions
- Use voltage inputs and current outputs wherever possible
SPICE tips – bounded matrix

- Keep matrix equations as tightly bounded as possible
  - Place limits on gain and buffer stages
  - Use only as much gain as required
  - Scale resistances to keep node voltages and currents in similar ranges
SPICE tips – simplified components

• Replace complex components with simple approximations if exact component modeling isn’t necessary
  – **Example:** ideal diode → voltage-controlled switch

Diode equation: \( i_D = I_S \left( e^{\frac{qV_D}{kT}} - 1 \right) \)
Thank you!
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