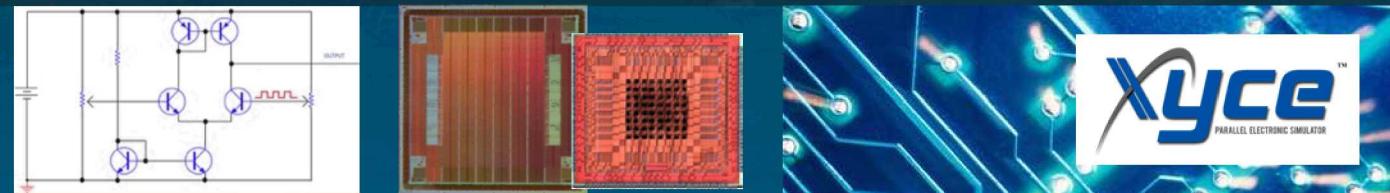




# AMS Verification Technologies and Flow for enabling POSH SoCs



*PRESENTED BY*

Eric Keiter, PI

Sandia National Laboratories



SAND2019-7962PE

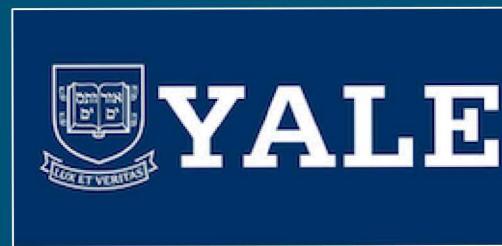


Part 1: Xyce open source circuit simulator (Sandia)

<http://xyce.sandia.gov>



Part 2: FGPA Hardware Emulation (Yale)





# The Xyce Analog Circuit Simulator

SPICE-Compatible syntax (Berkeley 3f5)

Not “Fast SPICE”

Two versions, **Serial** and...

**Distributed Memory Parallel** (MPI-based)

Unique solver algorithms

Industry standard models

Non-traditional models

- Neuron/synapse
- TCAD (PDE-based)

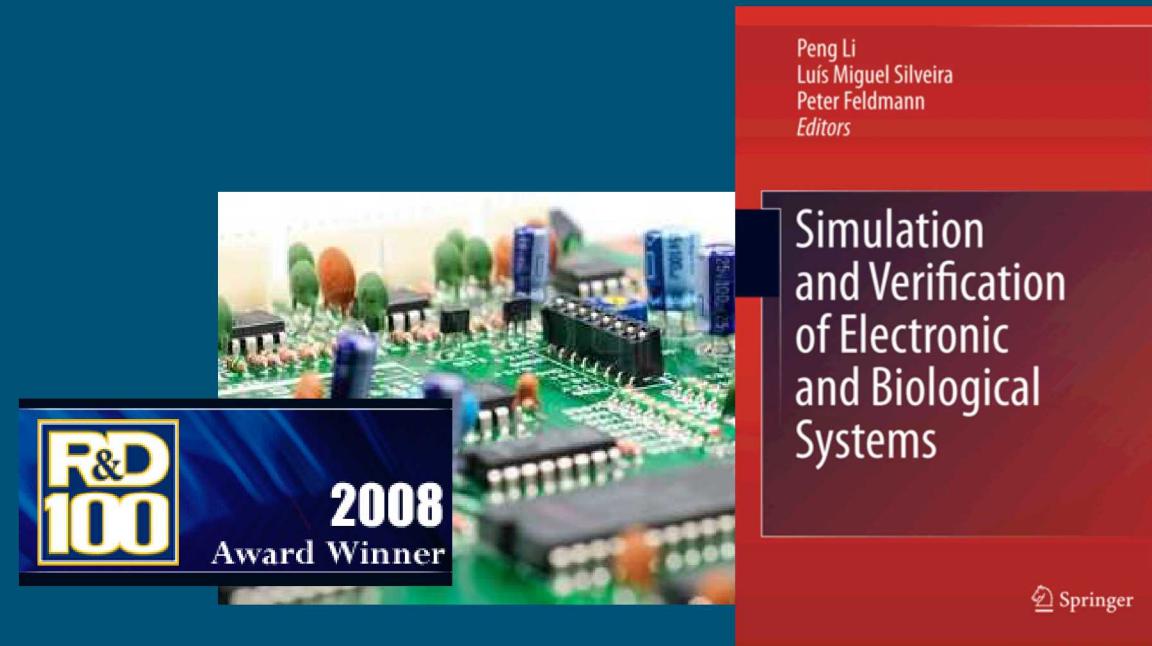
<http://xyce.sandia.gov>

## Open Source, GPLv3

- Since September of 2013 (Xyce 6.0)

Xyce Release 6.11.1

- June, 2019; 24th major release
- >4.700 registered downloaders



Keiter, et al.,  
“Parallel  
Transistor-Level  
Circuit Simulation”

fundamental research

# Xyce Capabilities



## Typical

DC, Transient, AC, Noise

- .DC, .TRAN, .NOISE, .AC (and .STEP)

Post Processing:

- Fourier transform of transient output (.FOUR)
- Post-simulation calculation of simulation metrics (.MEASURE)

Output (.PRINT)

- Text Files (tab or comma delimited)
- Probe (PSPICE)
- Gnuplot, TecPlot, RAW (SPICE 3f5)

Analog Behavioral Modeling

Expressions, functions, parameterizations...

## Others

Harmonic Balance Analysis (.HB)

- Steady state solution of nonlinear circuits in the frequency domain

Random Sampling Analysis

- Executes the primary analysis (.DC, .AC, .TRAN, etc.) inside a loop over randomly distributed parameters

Sensitivities

- Computes sensitivities for a user-specified objective function with respect to a user-specified list of circuit parameters ( $\partial O / \partial p \dots$ )
- DC or Transient
- E.g., an output voltage's dependence on a capacitance

# 6 Obtaining Xyce



## Xyce at Sandia

- **Binary executables** for Windows, OSX and Red Hat Enterprise Linux 6 & 7
- **Xyce** release source code, **build instructions** and more...

<https://xyce.sandia.gov>

## GitHub

- For the latest **stable changes** to the **source code** between releases

<https://github.com/xyce>

The image displays two screenshots of the Xyce software interface. The left screenshot is the official Xyce website at <https://xyce.sandia.gov>. It features a dark background with a blue glowing network or circuit pattern. The main heading is 'Xyce' with the tagline 'Parallel electronic simulation'. Below this are sections for 'About Xyce', 'News & Publications' (listing 'Xyce 6.11.1 Released!', 'View All News', and 'View All Publications'), and 'Contact Xyce'. A large 'Download Xyce 6.11.1' button is at the bottom. The right screenshot is the Xyce repository on GitHub at <https://github.com/xyce>. It features a prominent 'Now on GitHub!' banner. The GitHub interface shows 'Repositories 2', 'People 4', and 'Projects'. The repository 'Xyce\_Regression' is listed with a Perl file, 2 stars, 0 forks, 0 issues, and was updated 3 days ago. The repository 'Xyce' is listed with a C file, GPL-3.0 license, 1 star, 8 forks, 0 issues, and was updated 3 days ago. The 'People' section shows four GitHub profiles. The bottom of the GitHub screenshot includes a footer with links to 'Contact GitHub', 'Pricing', 'API', 'Training', 'Blog', and 'About'.

# Resources on the Sandia Site

Go to our website: Click on the download button, fill out form

At download page, many resources are available.

- **Binary executables** for Windows, OSX and Red Hat Enterprise Linux 6 & 7
- **Xyce Source code and build instructions**
  - If you do this, follow instructions carefully.
  - You must build the Trilinos library with the EXACT options we specify.
  - <https://trilinos.org/>
- **Regression test suite** (several thousand tests)
- **Documentation**
  - Users guide
  - Reference guide
  - Mathematical Formulation
  - Release notes
  - FAQ
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  - Hpice compatibility App note

**<http://xyce.sandia.gov>**



The screenshot shows the homepage of the Xyce website at <https://xyce.sandia.gov/index.html>. The page features a header with the Sandia National Laboratories logo and navigation links for About, Programs, Research, Working with Sandia, News, and Careers. Below the header is a banner with the text "Xyce" and "Parallel electronic simulation" over a blue background with abstract circuit patterns. The main content area includes sections for "About Xyce" (describing Xyce as an open-source analog circuit simulator), "How to Get Access" (mentioning the GNU General Public License), and a "News & Publications" sidebar with links to news and publications. At the bottom is the Xyce logo with the tagline "PARALLEL ELECTRONIC SIMULATOR".

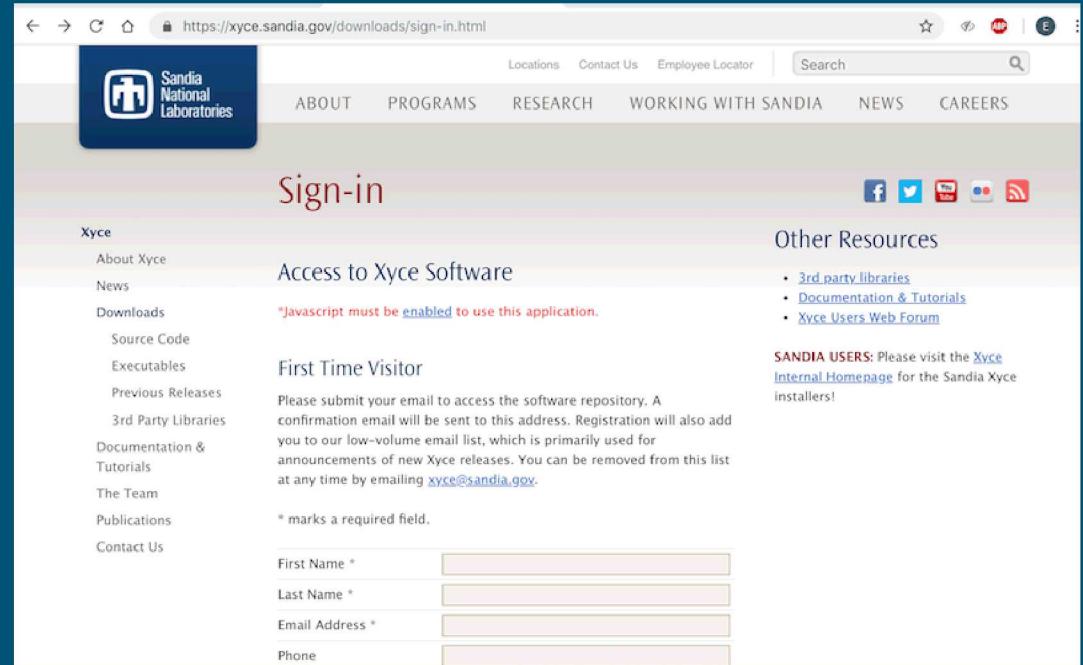
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The screenshot shows a web browser displaying the URL <https://xyce.sandia.gov/downloads/sign-in.html>. The page is titled "Sign-in" and is part of the "Xyce" section of the Sandia National Laboratories website. The page includes a sidebar with links to "About Xyce", "News", "Downloads", "Source Code", "Executables", "Previous Releases", "3rd Party Libraries", "Documentation & Tutorials", "The Team", "Publications", and "Contact Us". The main content area contains a "Access to Xyce Software" section with a note about enabling Javascript and a "First Time Visitor" section with instructions for email submission. On the right, there is an "Other Resources" sidebar with links to "3rd party libraries", "Documentation & Tutorials", and "Xyce Users Web Forum". A note for "SANDIA USERS" directs them to the "Xyce Internal Homepage". The page features a standard header with links to "Locations", "Contact Us", "Employee Locator", and a search bar.

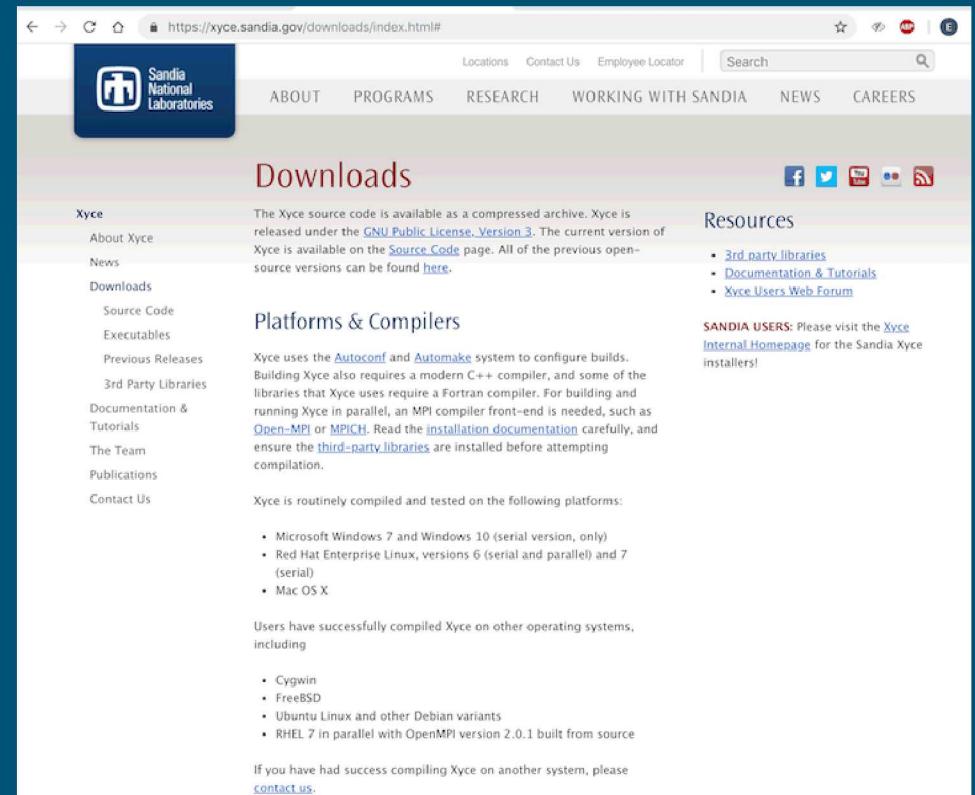
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The screenshot shows a web browser displaying the Sandia Xyce download page. The URL in the address bar is <https://xyce.sandia.gov/downloads/Binaries.html>. The page features the Sandia National Laboratories logo and a navigation menu with links to About, Programs, Research, Working with Sandia, News, and Careers. The main content area is titled 'Binaries' and specifically lists 'RedHat Enterprise Linux 6 and 7, 64-bit'. It includes a note about the distribution method (open-source source code vs. executables) and a list of available builds (Serial build (RHEL6), Parallel build (RHEL6), Serial build (RHEL7)). Below the list, there is a command to install the binaries using 'sudo yum install <filename>.rpm'.

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The source code for the current version of Xyce is available for download here: [Xyce-6.10.tar.gz](https://xyce.sandia.gov/xyce-6.10.tar.gz).

The pdf-based documentation is in a separate download here: [Xyce\\_Docs-6.10.tar.gz](https://xyce.sandia.gov/Xyce_Docs-6.10.tar.gz). Be sure to consult the [Building Guide](#) page for instructions on building Xyce from the source code. All documentation, including a list of errata pages, can be found on the [Documentation](#) page.

The Xyce test suite is available here: [Xyce\\_Regression-6.10.tar.gz](https://xyce.sandia.gov/Xyce_Regression-6.10.tar.gz). See the [Running the Test Suite](#) page for instructions.

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<http://xyce.sandia.gov>

The screenshot shows a web browser displaying the 'Building Guide' page for Xyce. The page is titled 'Building Guide' and includes sections for 'Introduction', 'Overview', and 'Build Directories'. The 'Introduction' section provides a brief overview of the guide and its prerequisites. The 'Overview' section details the general steps for installing Xyce from source code. The 'Build Directories' section notes that the recommendations for building Trilinos and Xyce use 'out-of-source' builds. The left sidebar contains a navigation menu with links to 'About Xyce', 'News', 'Downloads', 'Documentation & Tutorials', 'Building Guide' (which is the current page), 'Running the Xyce Regression Suite', 'Users' Guide Errata', 'Reference Guide Errata', 'Frequently Asked Questions', 'Xyce/ADMS Users Guide', 'Tutorial: Adding a device to Xyce', 'The Team', 'Publications', and 'Contact Us'. The top navigation bar includes links for 'Locations', 'Contact Us', 'Employee Locator', 'Search', and categories for 'ABOUT', 'PROGRAMS', 'RESEARCH', 'WORKING WITH SANDIA', 'NEWS', and 'CAREERS'.

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**<http://xyce.sandia.gov>**



The screenshot shows a web browser displaying the Xyce documentation page at <https://xyce.sandia.gov/documentation/RunningTheTests.html>. The page features the Sandia National Laboratories logo in the top left. The main content is titled "Running the Xyce Regression Suite" in a large, bold, dark red font. Below the title, there is a detailed description of the regression suite, mentioning its purpose, how it is run, and its components. To the left of the main content, there is a sidebar with a blue header containing the "Xyce" logo and a list of links to various Xyce documentation pages. The sidebar includes links for "About Xyce", "News", "Downloads", "Documentation & Tutorials", "Building Guide", "Running the Xyce Regression Suite" (which is the current page), "Users' Guide Errata", "Reference Guide Errata", "Frequently Asked Questions", "Xyce/ADMS Users Guide", "Tutorial: Adding a device to Xyce", "The Team", "Publications", and "Contact Us". The main content area also includes social media sharing icons (Facebook, Twitter, YouTube, LinkedIn, RSS) and a search bar at the top.

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The screenshot shows the 'Documentation & Tutorials' section of the Xyce website. The sidebar on the left includes links for Xyce, About Xyce, News, Downloads, Documentation & Tutorials, Building Guide, Running the Xyce Regression Suite, Users' Guide Errata, Reference Guide Errata, Frequently Asked Questions, Xyce/ADMS Users' Guide, Tutorial: Adding a device to Xyce, The Team, Publications, Contact Us, and Web forum. The main content area is titled 'Documentation & Tutorials' and lists various PDF documents available for download, including Release Notes (PDF), Users' Guide (PDF), Reference Guide (PDF), Building Guide (instructions for building Xyce from the source code), Mathematical Formulation (PDF), Using Open Source Schematic Capture Tools With Xyce (PDF), Power Grid Modeling with Xyce (PDF), and a compressed archive of example netlists for power grid modeling. It also mentions the Xyce Regression Test Suite and Frequently Asked Questions. The Xyce/ADMS Users' Guide and Tutorial: Adding a new compact model to Xyce are also listed. A note at the bottom indicates that all the documents can be downloaded as a single, compressed archive at [Xyce\\_Docs-6.10.tar.gz](#).

# Xyce Release 6.11.1 Highlights



Initial S-parameter Analysis capability, including support for the P (port) device

HSPICE compatibility improvements

- Charge-based capacitor model
- Pattern (PAT) source function
- Parsing compatibilities (X for  $10^6$ , nested delimiters, C-style ternary expressions, e.g.)
- `-hspice-ext` command line option for certain Xyce-incompatible HSPICE features

Improvements of .MEASURE

- .AC analysis now supported
- Added MEASFAIL, MEASDGT and MEASOUT

Parameter sensitivities

- .AC analysis now supported
- Transient direct sensitivities can now be processed using .FOUR

Performance enhancements and bug fixes

- Up to 4× speed enhancements for some simulations



HSPICE compatibility is the initial solution for making PDKs available to Xyce

Application Note available on the Xyce website

- Differences between HSPICE and Xyce (syntax and features)
- Viewing Xyce output files in WaveView
- A step-by-step guide for translating HSPICE to Xyce

The Xyce team has successfully translated

- GF 14nm PDK
- GF 65nm PDK
- and can help other performers with similar translations.

XDM Translator

- A tool for automatically translating HSPICE (& PSpice) netlists into Xyce syntax
- Should handle most translation tasks, with incompatible lines highlighted
- Available with the Xyce 7.0 release



“Coming Soon”

## Major features

### XDM

#### Initial CMake refactor

- Improved ease of compiling Xyce on all platforms
- Robust against variations in third-party libraries, particularly Trilinos
- Streamlined and faster configuring on all platforms

#### Also

- More HSPICE compatibility improvements
- More performance improvements

# Xyce Resources

This week, we are here:



**Eric Keiter, Sandia**

- Circuit simulation, Xyce
- UW-Madison, Plasma Simulation



**Jason Verley, Sandia**

- Circuit simulation, Xyce
- Colorado School of Mines, Solid-State Physics



**Heidi Thornquist, Sandia**

- Parallel algorithms
- Linear solvers
- Model order reduction
- Rice University, Applied Math

After this week:

- Tutorial Videos (on documentation website)
- Feel free to contact us (me) directly
- Xyce mailing list: [xyce@sandia.gov](mailto:xyce@sandia.gov)
- Xyce google group:  
<https://groups.google.com/group/xyce-users>

The screenshot shows the Google Groups interface for the 'XYCE-USERS' group. The group is described as a shared public forum with 61 of 162 topics. The welcome message explains the subscription process. The sidebar includes links for 'Groups', 'New topic', 'Favorites', and 'Recently viewed'. The main content area shows a list of recent posts, including topics like 'Xyce Version 6.10 has been released', 'Multiple analysis in the same netlist', 'HB initial guess', 'Xyce(ADMS - erfcj)', and 'bsim-ling level78 version=102.00 support request'.

# Xyce Team Acknowledgements

Eric R. Keiter

Thomas V. Russo

Richard L. Schiek

Heidi K. Thornquist

Ting Mei

Jason C. Verley

Peter E. Sholander

Karthik V. Aadithya

...and many others

Contact:

<http://xyce.sandia.gov>  
[xyce@sandia.gov](mailto:xyce@sandia.gov)

Google Group Forum:

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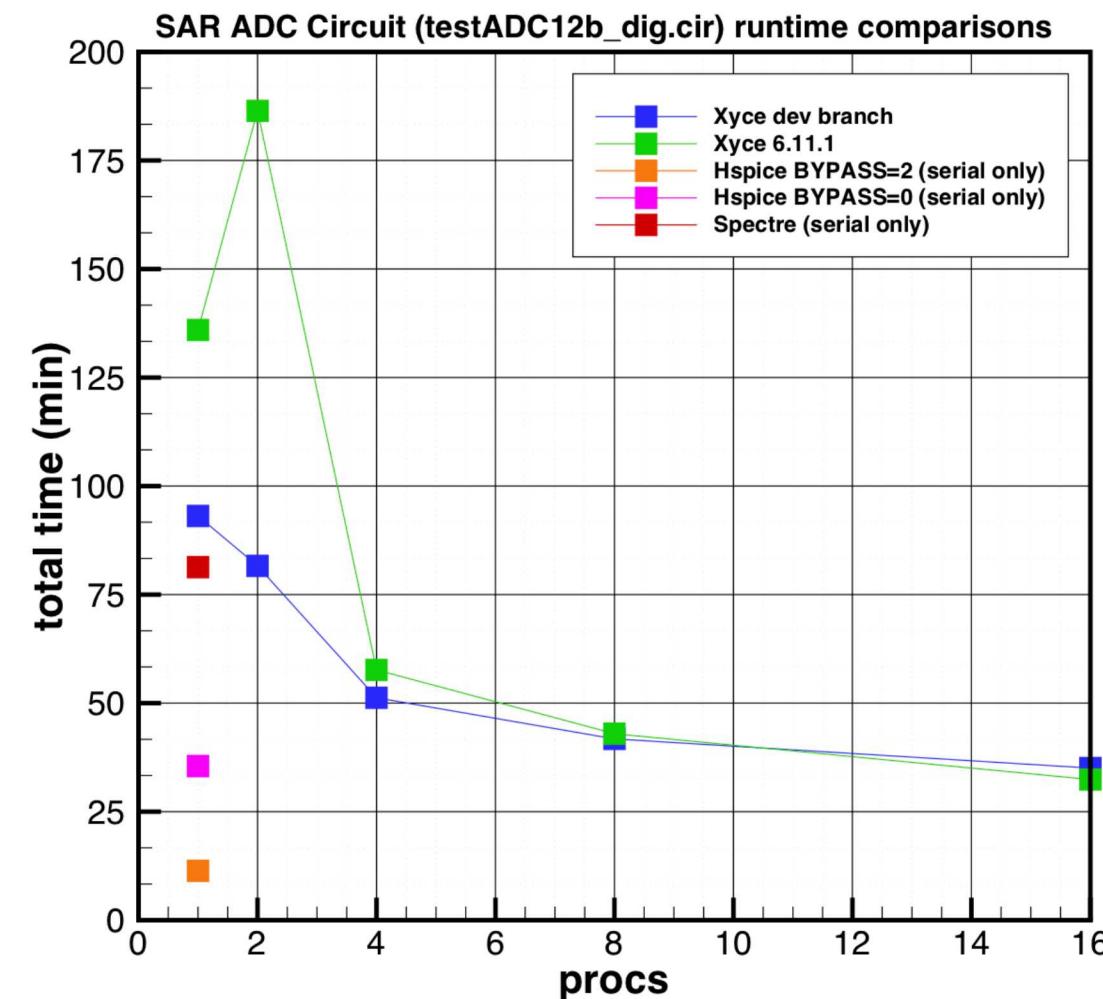




# SAR ADC timings, Xyce vs Hspice and Spectre

Recent efficiency improvements to Xyce have brought it close to Spectre for one processor.

Still work to do to catch Hspice. Some of the difference is due to BYPASS, which is present in Hspice, but not Xyce or Spectre.



# Comparison of SAR ADC Result, Xyce vs Hspice



## Results match well. RMS Errors small

RMS relative error in  $v(\text{sync})$  is 0.0434905680015374%

RMS relative error in  $v(\text{po}<0>)$  is 0.0232474456164593%

RMS relative error in  $v(\text{po}<1>)$  is 0.023581461963474%

RMS relative error in  $v(\text{po}<2>)$  is 0.02583082511786%

RMS relative error in  $v(\text{po}<3>)$  is 0.0240096727254828%

RMS relative error in  $v(\text{po}<4>)$  is 0.0166525520072121%

RMS relative error in  $v(\text{po}<5>)$  is 0.00929693070847055%

RMS relative error in  $v(\text{po}<6>)$  is 0.0309201017241085%

RMS relative error in  $v(\text{po}<7>)$  is 0.0230237794341722%

RMS relative error in  $v(\text{po}<8>)$  is 0.0259005260949305%

RMS relative error in  $v(\text{po}<9>)$  is 0.0175662606806119%

RMS relative error in  $v(\text{po}<10>)$  is 0.00940986678122403%

RMS relative error in  $v(\text{po}<11>)$  is 0.00976999004888706%

