

HICUM - User Support Update

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Santa Barbara
October 2005

HICUM / Level2 - Summary of activities

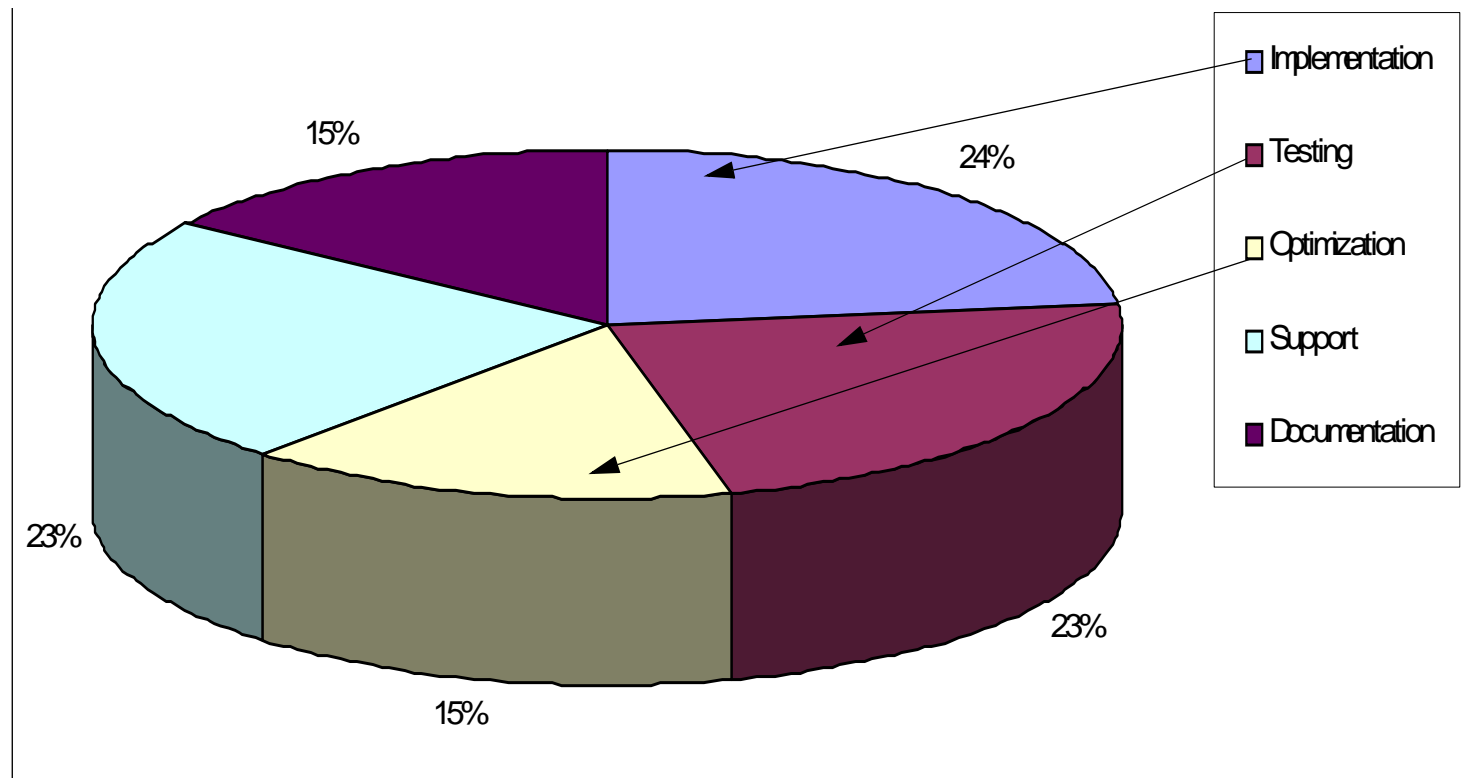
- Version 2.1
 - (re-)written in Verilog as reference (to replace DEVICE code) => major effort
 - support of EDA vendors (model implementation, testing, ...)
 - mainly Cadence, Synopsis
 - DEVICE related code (documentation vs implementation)
 - derivative checking (e.g. with Mathcad)
- Version 2.2
 - improvements to Verilog code (DC, AC, noise, ET)
 - based on feedback and questions from vendors
 - following coding guidelines from G. Coram, C. McAndrew, I. Yusim, L. Lemaitre
=> Verilog related optimization
 - Verilog compilers:
 - set up of ADMS (SPECTRE as lead simulator for testing) with help from I. Yusim
 - Tiburon: linked to ADS (as lead HB simulator, with help from F. Sischka)
 - implementation related investigation: NQS effects, correlated B-C-current noise
- Documentation
 - updated version available on new web-site (incl. parameter ranges, fixes, ...)

HICUM / Level0 - summary

- Version 1.1
 - improved Verilog implementation
 - based on Level2 coding experience
 - equation extensions: avalanche current, rBi, self-heating, limitation for diode currents
- Model compilers
 - Level0 (due to its simplicity) was initially used to set up model compiler
 - excellent help from Cadence to obtain consistent version at both sites
- Documentation
 - see new web-site
 - not as complete yet as for Level2 (lack of time)

General remarks

- new website: better and systematic presentation of HICUM related material
- time allocation: percentage hours consumed since mid-January '05



Special thanks for their help to

Geoffrey Coram (ADI)
Colin McAndrew (Freescale)
F. Sischka (Agilent)
I. Yusim (Cadence)
L. Lemaitre (Freescale)

Q&A Section - Level2/v2.1

... from Dave Sheridan's recent feedback summary

- Q1 quoted directly from Cadence HiCUM presentation:

"Simplified equations for transconductance and diffusion capacitance
All these simplified forms are inconsistent with charge and current computed from
Newton iterations and cause convergence issue during transient analysis
Not unique for Spectre, it is problematic for all simulators ! “

- A1:

- the equations cited come from the DEVICE implementation, which has been proven to be sufficient for high-speed circuit design applications
- specifically: $C_{dci} = T_r * S_{rb} + T_f * S_{fc} \Rightarrow$ resulted from *small-signal circuit design* requirement for frequency dependent output conductance
- transient simulation convergence is not affected at all by the derivatives, but PSS and possibly also HB analysis can be
- we are aware of the more stringent requirements in commercial circuit simulators

Solution: use Verilog code \Rightarrow C code with symbolic derivatives

Q&A Section - Level2/v2.1

- Q2 quoted directly from Cadence HiCUM presentation:
"Missing temperature derivatives for diodes
Missing part Jacobian for internal base resistance function
 $dR_{bi_dV_{be}}$, $dR_{bi_dV_{bc}}$, $dR_{bi_dV_{ce}}$ "
- A2:
 - the impact of the RBI derivatives on circuit characteristics were checked and found to have no impact => dropped in DEVICE

Solution: Verilog generated C code

- Q3: Some smoothing functions are not continuous at boundary
- A3:
 - which ones ? Version 2.1 ? Please provide examples
 - v2.2 has improved smoothing functions

Solution: Verilog code of v2.1

(can import smoothing from v2.2 if requested => why not use v2.2?)

Q&A Section - Level2/v2.1

- Q4: Fortran code for V2.1 on the web site is old, and does not contain the fixes that are mentioned in the V2.2 update documentation. [namely:]
 - Q_dS computed from I_TS instead of I_TSf
 - I_Tsf uses V_BxCi instead of V_BpCi
- A4:
 - fixed in codes and new documentation
- Q5 (David Sheridan): when will the C-code with analytic derivatives be available?
- A5:
 - can be generated at any time

Q&A Section - Level2/v2.1

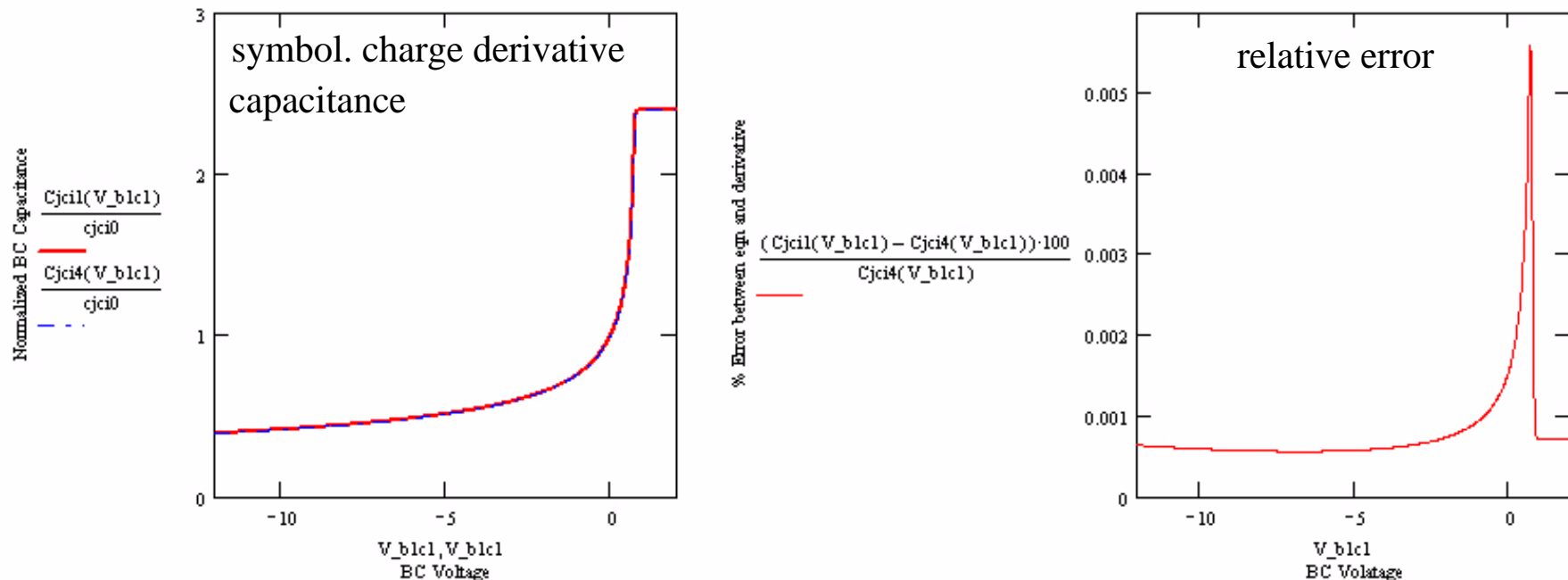
- Q6: V2.1 Fortran version does not contain complete derivatives and no Verilog-A V2.1 is available for checking/implementation.
- A6:
 - Verilog v2.1 code is available to replace FTN code
- Q7: The documentation indicates full self heating (2.1.16-1), but the Fortran code does not.
- A7:
 - investigations have shown that evaluating the other terms adds CPU time but no significant accuracy improvement, especially compared to the uncertainty in RTH, CTH values
 - => left out (corresponds to good approximation of heat term) in v2.1.a
 - for commercial applications full derivatives may be desired

Solution: Verilog V2.1.b with all terms

Q&A Section - Level2/v2.1

- Q8: QCJMOD smoothing problem
- A8: The difference between the capacitance equation and the symbolic derivative of the charge was found to be negligible: < 0.016% relative error.

Further action: VPT has been limited to 100V to avoid issues under extreme conditions (bad parameter combination and large reverse bias)



Cjc1: actual equation, Cjc14: Symbolic derivative of charge eq.. Parameters: cjc10=1.16e-15, zc1=0.333, vdc1=0.8, vptc1=100, T=300.15K.

Q&A Section - Level2/v2.1

- Q9: Possible division by zero error in the conductivity modulation factor for Rbi with non-physical parameter sets in V2.1 (See Agilent HiCUM 2.1 Compatibility report by Rick Poore)
- A9:
 - this would happen only for **extremely** unrealistic model parameters and device operation
 - fixed in v2.1 and v2.2 code by deleting BC depletion charge component however: QjCi should be included for physical and accuracy reasons
=> smoothing function to avoid total charge to become negative

Q&A Section - Level2/v2.1

- Q10: The HiCUM documentation and DEVICE code both put the BP-EI current (ibep) flicker noise across the BI-EI junction. Some simulators chose to put this across BP-EI which Analog believes to be correct
- A10:
 - the location of the noise sources depends on the physical origin of the flicker noise, but the physical origin of flicker noise is not well-known in many processes
=> the correct and most flexible implementation would include a separate flicker noise source for each diode component (and the recombination current diodes) PLUS a correlation coefficient between the currents
 - The original HICUM documentation and implementation assumed the noise to be fully correlated (i.e. resulting from the same noise source), which was experimentally evident for processes technologies at that time
=> this may have changed in present process technologies

Q&A Section - Level2/v2.1

- Q11: Parameter ranges are not documented
- A11:
 - they are now - in the new documentation (also available in the Verilog codes)

Note: we did document the small-signal output ...

... but not many vendors have followed the documentation

- Q12: Version control and bug fix log on HiCUM website
- A12:
 - consideration of efficient and easy to handle system is in progress
 - set-up after reorganizing the web-site

Q&A Section - Level2/v2.2

- Q1: Parameter name changes (aljei -> ajei, and ccox -> cbcpar) are troublesome for backward compatibility issues.
- A1:
 - why not keep both names available for a certain period of time ?
(being done in a lot of models and codes)
 - how will model development be "managed" (effort is not being paid for by CMC)?
- Q2: Parameter name changes (aljei -> alei, and ccox -> cbcpar) are troublesome for backward compatibility issues.
- A2:
 - why not keep both names available for a certain period of time ?
(being done in a lot of models and codes)
 - how will model development be "managed" (effort is not being paid for by CMC)?

some of the v2.1 related Q&A's also apply to to v2.2