CMC OMI - Open Model Interface

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Traditional Model Library Approach

History:

With devices shrinking in size layout implementation is not reflected in the basic device model card and cover all the components to realize an electrical device in a circuit. Traditionally people have included sub-circuits round the basic device model card to get the full electrical representation but this involves extra elements in the circuit matrix to be solved. With circuits containing more and more elements this just multiplies the problem of the matrix size to be manipulated and solved at every step of the simulators analysis stage.

Change:

A different approach is to have an extra compute shell around the basic model card to calculate and feedback different model parameters to the basic model card. In this way the circuit matrix does not expand and a speed improvement in simulation time is seen as the solver has less elements to manage compared to the sub-circuit approach. This is the basis of the Open Model Interface (OMI)

This type of simulation approach was first done by TSMC with limited users but is now Licensed to the CMC to develop and make available to all simulator vendors and foundries.

Here is example of the interactive flow:
OMI – Simulation flow overview and interaction with simulator

OMI flow overview and interaction with simulator
TMI – OMI File structure

```
CMC_TM2d0cl_2010_1207
  code/
    include/  src/  etc.
    Makefile  tmlDef.h  src
    tmlDef.h  get_os  config
    tmlBinTree.h  ut/
    tmlBinTree.h  simi/
    tmlHash.h  pcoporting/
    tmlHash.c  models/
    tmlcdef.h  tmlsp
    tmlMain.c  tmlcsp
    tmlMain.c  tmlcsp
    tmlHash.c  tmlcsp
    tmlHash.c  tmlcsp
    tmlHash.c  tmlcsp
    tmlcsp
  common/
    tmlAge.h
  tsim4/
    Makefile
    tmlBStM4Dat.h
    tmlBStM4ft.h
    tmlBStM4c.
    tmlBStM4GetParam.c
    tmlBStM4GetModelParam.c
    tmlBStM4intParam.c
    tmlBStM4intModelParam.c
    tmlBStM4set.c
    tmlBStM4setModelParam.c
    tmlBStM4Temp.c
    tmlBStM4Eval.c
    tmlBStM4ft.c
  (psp7)
```
OMI – TMI Additional capability

- As well as interacting with the existing model and matrix to be solved extra elements in the matrix can be added:

**Simulator (example only)**

1. **Start**
2. **Initialization and Topology Setup**
3. **Evaluation of additional components**
4. **Matrix Stamp**
5. **Matrix Solver**

**TMI**

- `tmiCreate()`: to return interface function addresses
- `tmiEvaluate(0)`: to determine node collapse
- `tmiTermCount()`: to return number of new nodes after collapse
- `tmiSetTopology()`: to update topology of standard models

- `tmiEvaluate(iter)`: to calculate I, Q and their derivatives
- `tmiNoise()`: to calculate thermal and flicker noise after `tmiEvaluate()`

To put I, Q and and their derivatives into the matrix. Values are available either by direct access to the TMI data structure (`tmiNoiseData`) or through TMI interface functions (I, G, Q, C) like:

- `tmiConstCondCount()`
- `tmiConstCondValue()`
- `tmilSize()`
- `tmilderivTermCol()`
- `tmilQSize()`
- `tmilQderivTermCol()`
Adding resistor element to circuit Topology

Start

After tmiEvaluate(0) determines node collapse conditions, tmiTermCount() returns new node number to simulators for node setup.

Simulators add one additional new node and send it back to TMI (tmiSetTopology) with other standard nodes.

tmiSetTopology() loads tmiBSIM4SpecData->node[], and map[], and then updates contents of stdNode[] and newNode[].

Simulators send node voltages based on stdNode[] and newNode[] to tmiEvaluate(iter) via tmiBSIM4OfWorkData->V[] for component.

TMI uses tmiBSIM4SpecData->node[] and calculated component values to do matrix stamping.

Simulators use stdNode[] to do Bsim4 matrix stamping.

End

stdNode[0]=0
stdNode[xg]=1
stdNode[xs]=2
stdNode[xb]=3
newNode[0]=4

Exchange

stdNode[xb]=4
newNode[0]=3

tmiBSIM4SpecData->
node[xd]=stdNode[xd]=0
node[xg]=stdNode[xg]=1
node[xs]=stdNode[xs]=2
node[xb]=stdNode[xb]=3
node[n0]=newNode[0]=4

stdNode[xg] (V[map[xg]])

stdNode[xd] (V[map[xd]])

stdNode[xb] (V[map[xb]])

stdNode[xs] (V[map[xs]])

V[map[xd]]=V[stdNode[xd]]
V[map[xg]]=V[stdNode[xg]]
V[map[xs]]=V[stdNode[xs]]
V[map[xb]]=V[stdNode[xb]]
V[newNode[0]]=V[newNode[0]]

Eg. lxbn0

tmiBSIM4ITermRow() returns
if (in.out == 0)
    return pBSIM4SpecData->node[map[xb]] /* 3 */
else
    return pBSIM4SpecData->node[map[n0]] /* 4 */
OMI Expanding Development

Development:

Development has lead to more than the original BSIM4 model and now we have BSIM-CMG (106.1), HiSIM2 and BSIMSOI added models.

We supply a model inclusion guide with the present code available to CMC members only at the moment while we test further the Beta release. We will release as a common standard for all to use once Beta testing and feedback is complete. CMC members will have access to a QA suite to validate the implementation of the model and reference results. Non CMC members will get the basic information without the QA suite.

Next I present one implementation using the HiSIM2 model to look at device degradation as the device is powered over a period of time:
Flow of aging model using OMI (Age integration)

- **Compact model**
  - Compact model parameter
  - Evaluate
  - \( t = t_1 \) (transient analysis)
  - \( t = t_1 + dt_2 \)

- **SPICE simulator**
  - Netlist reading
  - Compact model parameter
  - Time step \((t_1), Bias, Temperature, \ldots\)
  - Ids, Isub, \ldots

- **Aging model**
  - Parameter initialization
  - Aging model parameter
  - Age integration
  - Age @ \( t_1 \)
  - Age integration
  - Age @ \( t_1 + t_2 \)
Current activity:

While testing the Beta release we are looking to expand the simulator test cases to further exercise the model functionality. We are also expanding into Verilog-A as many models are now being released in this format.

This will require further expansion for extra parameter structures. To implement this capability we will need different model allocations since Verilog-A can be done for any model rather than one specific case like BSIM4. We are currently exploring the structures required for this functionality within the working group.

This will enable quick addition to the capability of OMI to add a lot more models into this interface.
OMI – Verilog-A considerations

OMI flow vs simulator parameter update flow to consider
CMC OMI Summary

Achievements:

1. 3 CMC standard models ready for OMI beta release
   BSIM4    BSIM-CMG    HiSIM2
   ( original code had just one simple device model case )
2. Set of test decks to test model interface and basic model functionality for all incorporated models – still expanding
3. Showed a reliability test using OMI interface
4. Ready to release beta 1 code for Group member feedback on flow and parameter usage

Future Plans:

1. Get test feedback on OMI flow and model functionality
2. Schedule incorporating OMI in vendor simulators
   ( talk with vendors to get schedule for interface in simulators )
   ( Cadence, Synopsys, Mentor, Silvaco, ProPlus etc. )
3. Look at incorporating other CMC standard models – people asked about HiSIM_HV and Mextram etc.
4. Continue exploring Reliability expansion
5. Look at core model structuring, since now so many models incorporated,

Issues to Resolve:

1. Version implementation in Final release
2. Decide about CMC QA test suite and what we include in public release
3. Will be talking to vendors to sort out simulator implementation time line

Thankyou to CMC members testing our releases and providing feedback
also for contributing model information

- Please let me know if you want more information
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