SIEMENS EDA



How to Extract Parasitic Inductance using Calibre xL

2024.2

Page 1 © Siemens 2024 | Siemens Digital Industries Software | Where today meets tomorrow.

Outline



- Objective
- Included Files
- Description
- Directions
- Conclusion



Objective



This Support Kit should help you understand how to:

- Understand the different use models and modes (PEEC/LOOP) that are supported in Calibre xL
- Use LOOP mode to extract Block level RCCLM
- USE PEEC mode to extract Block level RCC, and select critical nets RCCLM
- Extract a single RCCLM netlist in the same PEX run



Included Files



SIEMENS

File	Description
layout.gds	Sample GDS file
layout.gds.layerprops	Layer properties file to annotate the layer names
opamp.src.net	Sample spice netlist
runme	Script to run Calibre xRC
top.rules	top level rule deck that contains inductance rules
rules.pex	Parasitic capacitance rule deck
rules.lvs	LVS rule deck
rules.C	Calibrated Parasitic capacitance rule deck
rules.R	Calibrated Parasitic resistance rule deck
rules.xact	Calibrated Parasitic rule deck for xACT
mv-results.csh	Script to move the results of each run into the designated directory
cleanme	Script to clean up the run directory

Page 4 © Siemens 2024 | Siemens Digital Industries Software | Where today meets tomorrow.

Description >> Layout

View the sample layout file with the command:

calibredrv layout.gds



After examining the layout close Calibre DESIGNrev





Description



- Inductance parasitics occur due to the magnetic field generated by currents passing through conductors.
 These parasitics can impact on chip performance including signal delay, ringing, and overshooting
- Calibre xL provides a fast and accurate field solver-based inductance extraction engine to extract both self and mutual inductance parasitics of on-chip interconnects.
- Calibre xL is fully integrated with xRC, xACT and xACT3D to generate a single RCCLM netlist in a single PEX run.
- Calibre xL supports two modes: **LOOP** and **PEEC**
 - LOOP mode is associated with the extraction of loop self and mutual inductance for signal/return-path current loops in the layout. Only signal wires are represented in the netlist using the loop approach. The return path nets (PWR/GND) inductance values are included with the signal net values .
 - **PEEC mode** is associated with the extraction of parasitic "inductance" for straight wire segment. Both signal and ground segments, if selected, are represented in the netlist separately.



Description Pre-requisites for running Calibre xL

- 1. Calibre qualified deck with xRC , xACT, or xACT3D
- 2. Define extraction use model:
 - Block level RCC, and select critical nets RCCLM (LOOP or PEEC)
 - Block level RCCLM (LOOP mode)
- 3. Define the inductance extraction mode through **PEX INDUCTANCE MODE LOOP|PEEC**
- 4. Define the extraction frequency through **PEX INDUCTANCE FREQENCY**
 - LOOP can be run on a single frequency or across a broadband model
 - PEEC can only be run on a single frequency



Description >> Rule Deck



#IFDEF \$MODE LOOP
PEX INDUCTANCE MODE LOOP
PEX POWER SOURCE "vdd!"
PEX GROUND SOURCE "vss!"
PEX INDUCTANCE RETURNPATH GANDP
PEX INDUCTANCE RANGE 10
#ENDIF
#IFDEF \$MODE PEEC
PEX INDUCTANCE MODE PEEC NETS SOURCENAMES "VP" "VN" "VO"
#ENDIF

PEX INDUCTANCE MINLENGTH 10 PEX INDUCTANCE MAXIMUM FREQUENCY 5000000000

Only part of the rule deck is shown in this slide

The rule deck supports 2 runs: LOOP and PEEC

- For LOOP mode the following must be defined:
 - The power and ground nets using PEX GROUND and PEX POWER
 - The return path for the signal nets for self
 impedance calculations using **PEX INDUCTANCE RETURNPATH**
 - The search distance from net segments to look for the return paths using PEX INDUCTANCE RANGE
- For PEEC mode you must specify the nets of interest for inductance extraction using **PEX INDUCTANCE MODE PEEC NETS**

Description >> runme



#!/bin/csh -f

setenv MODE LOOP
calibre -lvs -hier top.rules |& tee lvs.log
calibre -xact -rcclm top.rules |& tee xact.log
mv-results.csh

setenv MODE PEEC
calibre -lvs -hier top.rules |& tee lvs.log
calibre -xact -rcclm top.rules |& tee xact.log
mv-results.csh

- runme file invokes 2 Calibre xACT runs:
 - With "MODE" = LOOP, it will run in LOOP mode, with the necessary settings on all the nets in the design
 - With "MODE" = PEEC, it will run PEEC mode on selective nets
- After every run, runme file invokes the mv-results.csh scripts, which:
- Renames the svdb and output netlist with respect to RUN_TYPE variable: svdb.\${MODE} and netlist.dspf.\${MODE}
- Creates a directory with the MODE variable name and moves the database, netlist and log files into it

SIEMENS



- From the terminal, execute the runme file:
- For the coming section, you will be directed into opening the following, created by each run
 - 1. The Standard Verification Database (SVDB) through Calibre Results Viewing Environment (RVE)
 - 2. xACT log files using any text editor
- Please make sure that you close the RVE after each results view in order to proceed to the next step: viewing the SVDB of the next run in-line





Directions >> Results LOOP mode

- Open the log file of LOOP run: LOOP/xact.log
- Look for "INDUCTANCE EXTRACTION OPTIONS" in the opened log file
- Notice The Following:
 - A warning message is issued that no victim nets are found for mutual inductance calculations
 - All the inductance extraction settings for the run are reported
 - The vss! and vdd! were recognized as return paths for the signal nets

WARNING: No victim net paths for mutual inductance calculations could be established. Please make sure a PEX INDUCTANCE VICTIM statement is present in the rule file.
INDUCTANCE EXTRACTION OPTIONS
Extraction Mode : LOOP Default global frequency (Hz) : 5e+09 Inductance range (um) : 10 Minimum length to compute self L (um) : 10 Return Path Mode : GANDP
WARNING: Missing/incomplete profile definition for layer PTAP - layer ignored WARNING: Missing/incomplete profile definition for layer NTAP - layer ignored WARNING: Missing/incomplete profile definition for layer PO2_nores - l ayer ignored
INFO: Return path nets found : vss! vdd!

LOOP mode needs Victim nets to be specified in order to extract mutual inductance. Victim nets are defined using **PEX INDUCTANCE VICTIM**

SIEMENS



Directions >> Results LOOP mode

 From the terminal, invoke Calibre RVE with the svdb created from the LOOP mode run:

calibre -rve LOOP/svdb.LOOP

- Notice The Following:
 - Parasitic Inductance for all signal nets is extracted
 - Since vss! and vdd! were recognized as return paths for the signal nets, their inductance values are included in the calculated inductance loop for signal net
 - No mutual inductance is extracted for any of the nets
 - Parasitic caps are extracted for all nets

Navigator 🕡 Info 🖥 🛪	🏂 opamp 🗙						
	No. Lavout Net	Source Net	R Count	L Count	C Total (F)	CC Total (F)	C+CC Total (F)
Results	1 vss!	VSS!	99	0	4.68731E-14	3.45421E-14	8.14153E-14
[₩] /Extraction Results	2 vdd!	vdd!	106	0	4.04158E-14	3.00119E-14	7.04278E-14
Comparison Results	3 3	3	68	30	1.71156E-15	1.70047E-14	1.87163E-14
the Demonstration	4 4	4	99	40	4.29598E-15	4.08727E-14	4.51687E-14
%ps Parasitics	5 5	5	74	31	2.93945E-15	4.04745E-14	4.34139E-14
Reports	6 VN	VN	3	3	3.05376E-16	7.12495E-15	7.43032E-15
E Extraction Report	7 VP	VP	3	3	3.15656E-16	7.12655E-15	7.44221E-15
LVC Deport		8	10	3	4.13632E-16	1.08868E-14	1.13004E-14
L LVS Report			1	0	5.54599E-16	2.1342/E-16	7.68025E-16
Separate Properties			1	0	0./0/10E-10 6.22527E-16	1.07220E-10	7.00337E-10
Rules	12 12	12		1	2 99074E-15	1.23733E-10	/ 90199E-15
🖓 Rules File	13 10	Vo	61	18	5.31798E-15	2.81886E-14	3 35066E-14
R		10	01	10	0.011002 10	2.010002 14	0.000002 14
view							
🕧 Info							
🚧 Finder							
Schematics							
- ·							
Setup							
Options							





Directions >> Results PEEC mode

- Open the log file of PEEC run: PEEC/xact.log
- Look for "INDUCTANCE EXTRACTION OPTIONS" in the opened log file
- Notice The Following:
 - The selected nets that were specified for the PEEC run are reported
 - All the inductance extraction settings for the run are reported

Se	elected nets: net VN net VP net VO		
	INDUCTANCE EX	TRACTION OPTIONS	
Ex De Mi	traction Mode fault global frequency (Hz) nimum length to compute self L (um)	: PEEC : 5e+09 : 10	





Directions >> Results PEEC mode

• From the terminal, invoke Calibre RVE with the svdb created from the **PEEC** mode run:

calibre -rve PEEC/svdb.PEEC

- Notice The Following:
 - Parasitic Inductance for the specified nets only is extracted, including self and mutual inductances
 - Parasitic caps are extracted for all nets

Eile <u>V</u> iew <u>H</u> ighlight <u>T</u> ools <u>W</u> indow <u>S</u> etup H <u>e</u> lp									
🎾 🖌 🔍 🖉 🖉	• 7	(``	🔥 🕵 🖳 s	earch	*	< >			
🛧 Navigator 🕜 Info 📑 🛪	🕸 op	amp ×							
Populto	No.	Layout Net	Source Net	R Count	L Count	K Count	C Total (F)	CC Total (F)	C+CC Total (F)
hesuits	1	vssl	vss!	99	0	0	4.68033E-14	3.42599E-14	8.10632E-14
Interpretation Provide the state of the	2	vdd!	vdd!	106	0	0	4.04857E-14	2.97775E-14	7.02632E-14
😃 Comparison Results	3	3	3	41	0	0	1.69930E-15	1.69227E-14	1.86220E-14
* Parasitics	4	4	4	61	0	0	4.26646E-15	4.06842E-14	4.49507E-14
Ager allastics	5	5	5	55	U	U 10	2.96529E-15	4.02952E-14	4.32605E-14
Reports	6	VN	VN	3	3	12	3.01862E-16	7.12846E-15	7.43032E-15
EXtraction Report	6	VP o	0 0	0	ა ი	12	3.14003E-16	1.12/40E-13	7.44220E-15
U I VS Report	0	0	0	3	0	0	4.13032E-10	1.00000E-14	1.13004E-14
D Concepto Descertion	10	5 10		1	0	0	5.82100E-16	2.12417E-10 1.84837E-16	7.66937E-16
Separate Properties	11	11		1	0	0	6.22527E-16	1.04007E-10	7.00337E-10
Rules	12	12	12	1	0	0	2 99694E-15	1.90505E-15	4 90199E-15
😴 Rules File	13	VO	VO	61	37	96	5.32025E-15	2.81867E-14	3.35070E-14
Mou									
view									
🕧 Info									
🚧 Finder									
Schematics									
Setup									
A Ontions									
- opuons									
	🗙 Fi	nd Nets: Typ	e in nets to search fo	1 T	Couplin	ig to: 💿 A	II Nets 🕜 Spe	ecified Nets Ty	pe in st 🎽 🔣 🎽

Mutual inductance is by default calculated for the selected nets that were specified for the PEEC run



How to Setup the LOOP inductance mode in Calibre xACT GUI



SIEMENS

	earch				
Rules Outputs Inputs xACT Mode xACT Outputs	Calibre <u>File</u> Settings	<u>C</u> onfigurations <u>H</u> elp		✓Search	From the "Inductance" tab:
Options Extraction Type LVS Peristance/Copacitance Database Inductance Environment No Inductance Run Control PET XACT Corner Triggers Co hers Templates PEX Netlist Preferences Search Xaks SVDB Ø Transcript PEX Report Point2Point Run xACT	Rules Inputs Outputs Options LVS Inductance Database Environment Run Control Triggers Templates	Inductance PEX Inductance Mode Mode Include Toplevel Layout Nets Include Toplevel Source Nets Include Recursive Layout Nets Include Recursive Source Nets PEX Inductance Range	LOOP Include Toplevel Layout Nets Include Toplevel Source Nets Include Recursive Layout Nets Include Recursive Source Nets Include Recursive Source Nets		Select your Inductance mode to LOOP Specify your Inductance range
From the "<i>Outputs</i>" tab:Select your Inductance	Preferences Search Transcript	 PEX Inductance MinLength Use PEX Inductance Victim File PEX Inductance Returnpath PEX Reduce MinMutual PEX Inductance Same Net Mutual 	10 victim.xl Ground and Power Enter the inductance coupling coefficient (K) threshold value Off		Specify the returnpath nets
	Run xACT	 PEX Inductance Frequency Use the broadband model Specify in Operating Frequency PEX Inductance Filter 	Giga Hertz 5		_Specify your frequency
		 PEX Power Supply Nets PEX Power Layout Nets PEX Power Source Nets PEX Ground Layout Nets PEX Ground Source Nets 	Specify PEX Power Layout Nets Vdd! Specify PEX Ground Layout Nets Vss!		Specify your power and ground nets

How to Setup the PEEC inductance mode in Calibre xACT GUI



SIEMENS

<u>File</u> <u>Settings</u> <u>Con</u>	nfigurations <u>H</u> elp	▼ Search				
Rules	Outputs	Calibre				
Outputs	xACT Mode XACT	File Settings Co	onfigurations Help	- Se	earch	From the "Inductance" tab:
Options	V Extraction Type		p			
Database	Recistance/Capacitance (RCC	Rules	Inductance		Calibre	Select your Inductance
Environment	L (Self Inductance)	Inputs	PEX Inductance Mode			mode to PEEC and include
Triggers	LM (Self + Mutual Inductance)	Outputs	Mode	PEEC		
Templates	> PEX Netlist	Options	Include Toplevel Source Nets	VP VN VO		the target nets for
Search	> Mask SVDB 🗹	LVS				inductance extraction
Transcript	> Reports	Database	PEX Inductance Range	10		
	> PEX Report Point2Point	Environment	REX Inductance MinLength	10		
Run xACT		Run Control				Optional filtering based on
Start RVE		Triggers	PEX Reduce MinMutual	Enter the inductance coupling coefficient (K) threshold value		
		Templates	PEX Inductance Same Net Mutual	Off	▽	vsignet net length for both
		Preferences	PEX Inductance Frequency 🗹 🖃			LOOP/PEEC (default is
		Search	✓ Use the broadband model			100,000
From u	ie <i>Oulpuls</i> lab.	Transcript	Specify in	Giga Hertz	•	Toounny
 Sele 	ect your Inductance		Operating Frequency	5		
						Specify your frequency
			PEX Inductance Filter 🗹			Specify your frequency.
			Net Filter	Арргох	•	Broadband model
			NOEX Dewer Supply Note			specification is ignored in
			• PEX Power supply Nets			
		Run xACT	PEX Power Layout Nets	Specify PEX Power Layout Nets		PEEC mode(not supported)
			PEX Power Source Nets	vdd!		
		Start RVE	PEX Ground Layout Nets	Specify PEX Ground Layout Nets		
			PEX Ground Source Nets	vss!		
						-

Inductance range settings, returnpath nets and power and ground nets settings are all ignored in PEEC mode

Conclusion



- Ignoring interconnect inductance extraction in analog and RC designs can be a fatal error. With frequency
 ranges for 5G communication exceeding 40Ghz, designers must ensure that their designs take into account
 post-layout resistance, capacitance, and inductance parasitics to confirm design simulation results match the
 silicon-fabricated results.
- Calibre® xL provides a fast, accurate field solver-based inductance extraction engine to extract both self and mutual inductance parasitics of on-chip interconnects.
- Calibre® xL can be easily streamlined in the verification flow since is fully integrated with Calibre® xRC[™], Calibre® xACT[™] & Calibre® xACT3D[™]. It offers various features including selected net extraction, customizable return path selection, and net-by-net frequency selection.
- Please refer to the Standard Verification Rule Format (SVRF) Manual, Calibre® xACT[™] User's Manual and Calibre® xRC[™] User's Manual for additional information.



Unpublished work. © 2024 Siemens

This software or file (the "Material") contains trade secrets or otherwise confidential information owned by Siemens Industry Software Inc. or its affiliates (collectively, "SISW"), or SISW's licensors. Access to and use of this information is strictly limited as set forth in one or more applicable agreement(s) with SISW. This material may not be copied, distributed, or otherwise disclosed without the express written permission of SISW, and may not be used in any way not expressly authorized by SISW.

Unless otherwise agreed in writing, SISW has no obligation to support or otherwise maintain this Material. No representation or other affirmation of fact herein shall be deemed to be a warranty or give rise to any liability of SISW whatsoever.

SISW reserves the right to make changes in specifications and other information contained herein without prior notice, and the reader should, in all cases, consult SISW to determine whether any changes have been made.

SISW MAKES NO WARRANTY OF ANY KIND WITH REGARD TO THIS MATERIAL INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY. SISW SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, CONSEQUENTIAL OR PUNITIVE DAMAGES, LOST DATA OR PROFITS, EVEN IF SUCH DAMAGES WERE FORESEEABLE, ARISING OUT OF OR RELATED TO THIS PUBLICATION OR THE INFORMATION CONTAINED IN IT, EVEN IF SISW HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

TRADEMARKS: The trademarks, logos, and service marks (collectively, "Marks") used herein are the property of Siemens AG, SISW, or their affiliates (collectively, "Siemens") or other parties. No one is permitted to use these Marks without the prior written consent of Siemens or the owner of the Marks, as applicable. The use herein of third party Marks is not an attempt to indicate Siemens as a source of a product, but is intended to indicate a product from, or associated with, a particular third party. A list of Siemens' Marks may be viewed at: http://www.plm.automation.siemens.com/global/en/legal/trademarks.html

Support Center: <u>https://support.sw.siemens.com/</u> Send Feedback on Documentation: <u>https://support.sw.siemens.com/doc_feedback_form</u>

