PathFinder-S ESD Analysis Training :

Apache Design Solutions Confidential

Agenda

Section-I : ESD Introduction

- ESD Overview
- ESD Event Types
- Technology and Design Challenges

Section-II : PathFinder™ ESD Solution

- PathFinder ESD Solution

Section-III : PathFinder-S HBM ESD Analysis

- HBM ESD Checks
- PathFinder-S HBM ESD Flow
- Input Data
- Output Reports
- Hands-On Tutorial Testcase
- Output Utilities

Agenda

Section-IV : CDM ESD Analysis

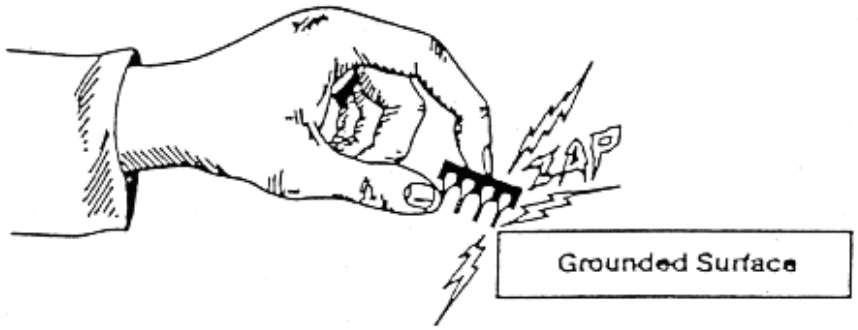
- CDM ESD Checks
- PathFinder-S CDM ESD Flow
- Input Data
- Output Reports
- Graphical Results
- Hands-On Tutorial Testcase

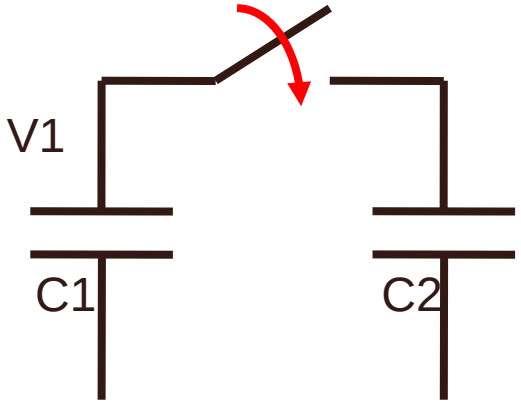
Section - I

ESD Introduction

Overview: What is ESD ?

- **ESD : Electro-Static Discharge**
  - Phenomenon related to charge sharing





Unexpected discharge:

- **Device damage: gate oxide, junctions**
- **Interconnect damage: metal and via**

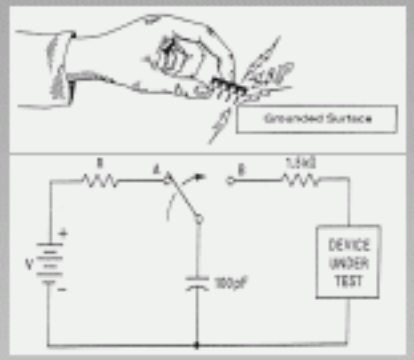
ESD protection device critical to prevent damage

ESD Event Models

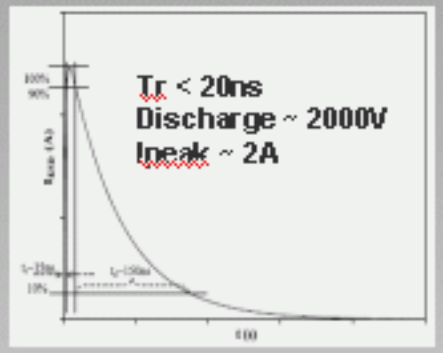
3 common models

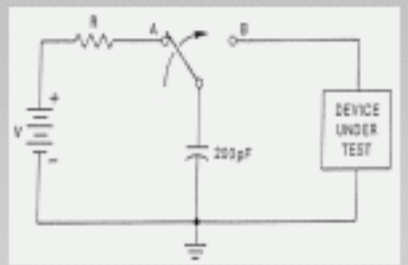
- HBM : Human Body Model
- MM : Machine Model
- CDM : Charged-Device Model

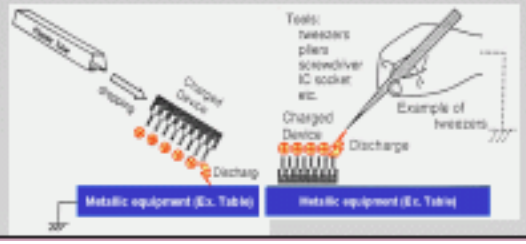
Model

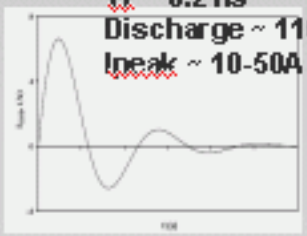


Discharging I waveform



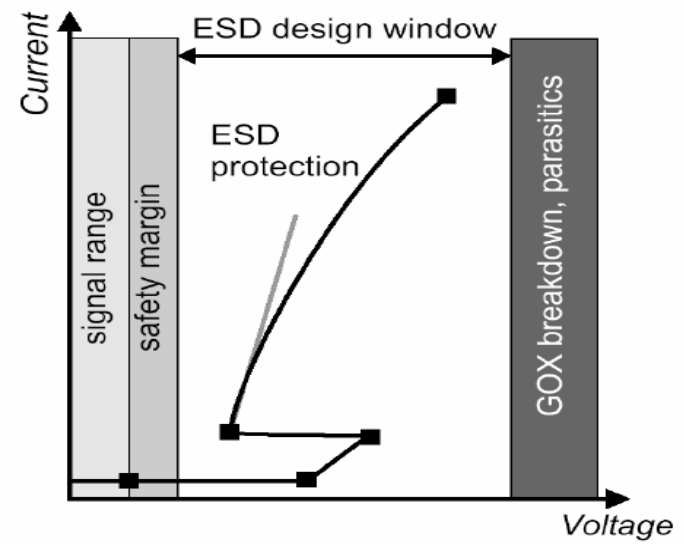


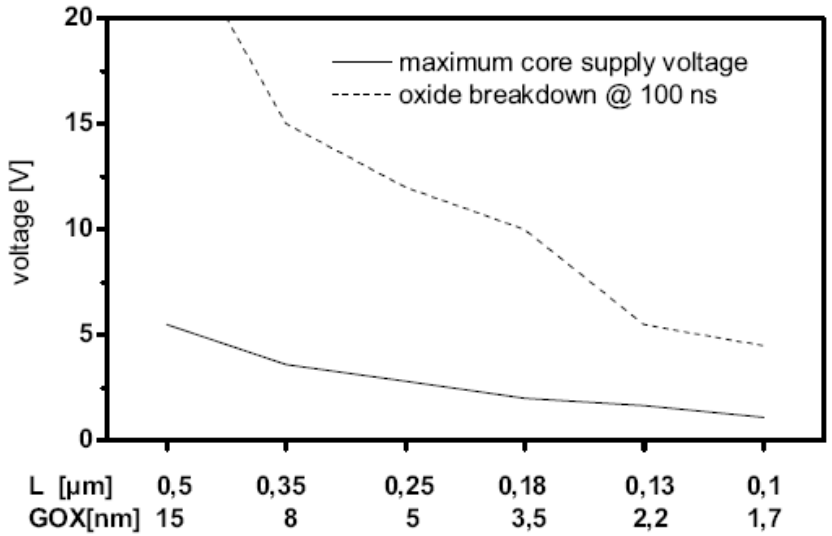




Challenges to ESD

- **Design Challenges**
  - Low-Power Designs
  - Impact on ICs Normal Operation
  - Chip Area Overhead to Ensure ESD Robustness
- **Technology Challenges**
  - ESD design window is compressed ⇗⇘ thinner gate oxide, lower junction breakdown voltages



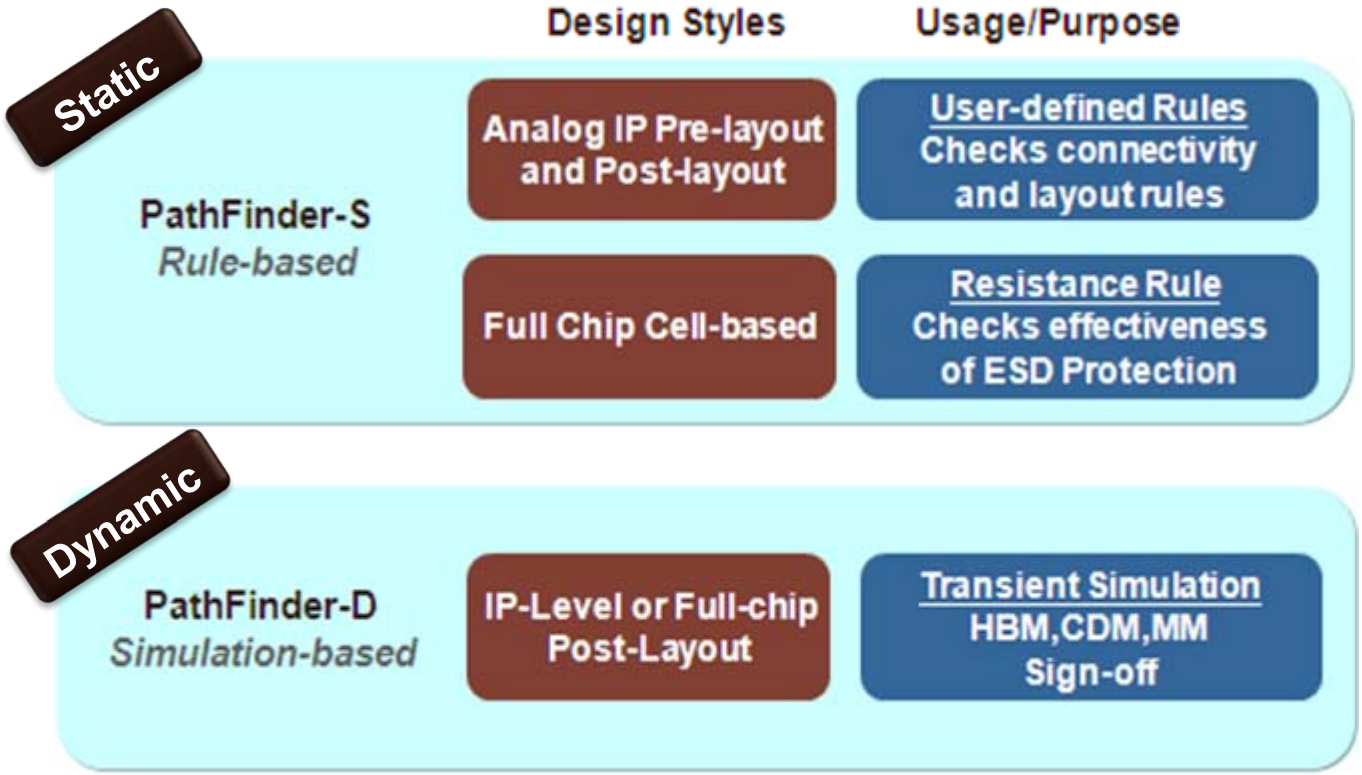


Section - II

PathFinder™ ESD Solution

PathFinder™ ESD Solution

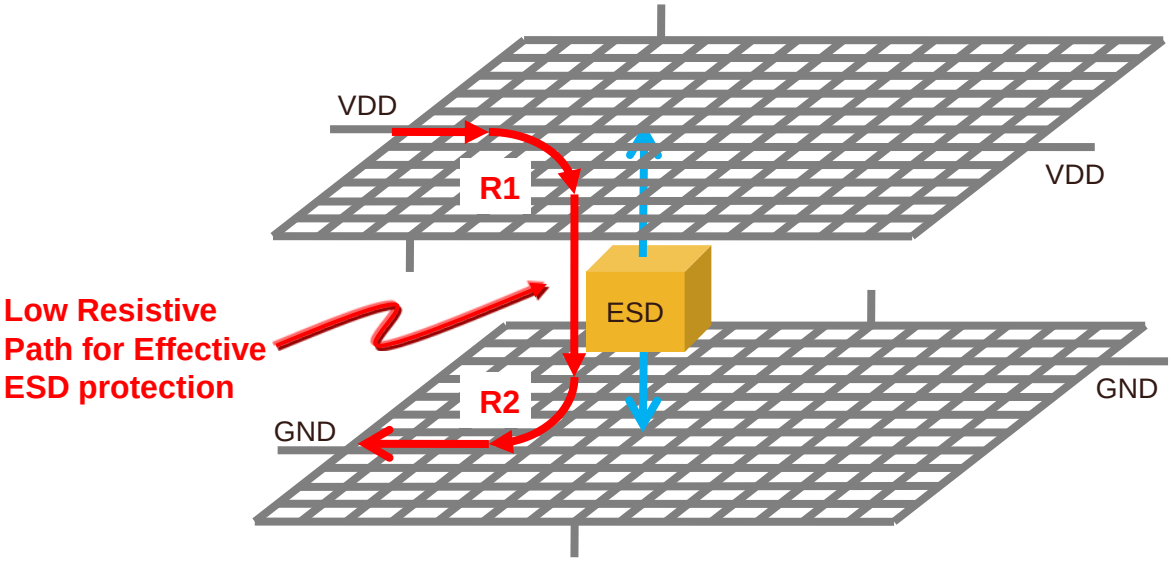
ESD Planning, Verification, and Sign-off



PathFinder ESD Checks

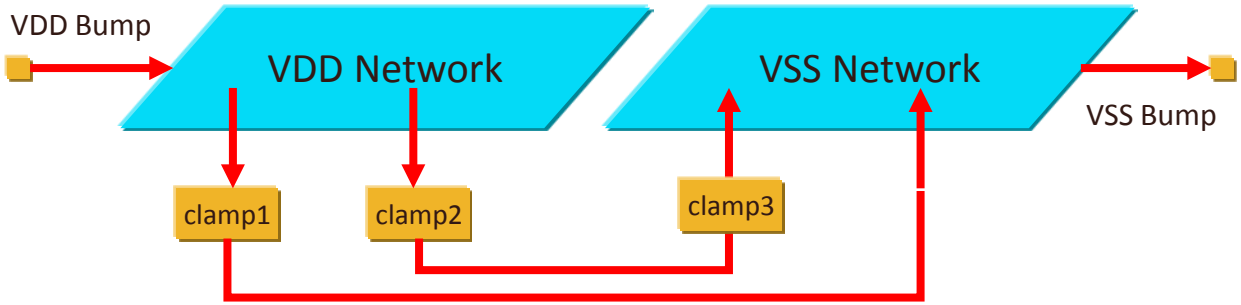
- Runs under RedHawk Framework
- Applicable to all three primary discharge events : HBM, MM, CDM

PathFinder-S HBM/MM Checks



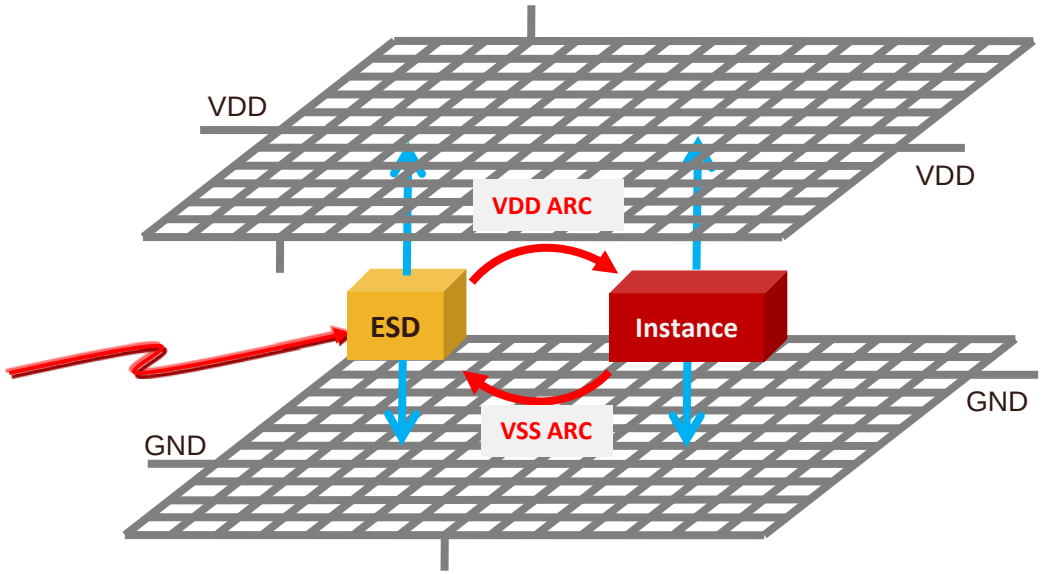
Rule Type:

- BUMP to BUMP
- BUMP to CLAMP
- CLAMP to CLAMP



Built-In Connectivity Planning and Verification

PathFinder-S CDM Checks



Low Resistive Loop for ESD protection

Rule Type:

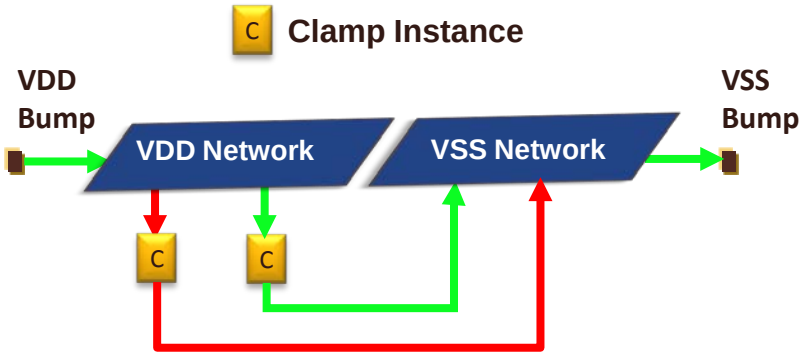
- CLAMP to INSTANCE
- CLAMP to MACRO

C2I or CLAMP2INST	Standard Cells, Pad Cells, Level Shifters, Tap Cells
C2M or CLAMP2MACRO	Memory Macro, Custom Macros

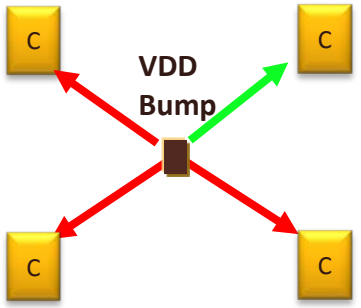
Section - III

PathFinder-S™ HBM ESD Analysis

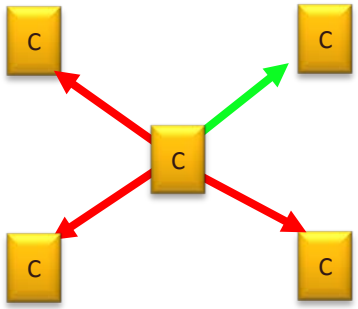
PathFinder-S HBM/MM ESD Checks



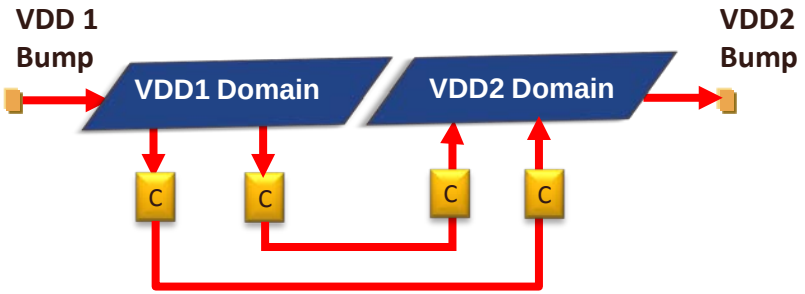
Bump2Bump (B2B)



Bump2Clamp (B2C)

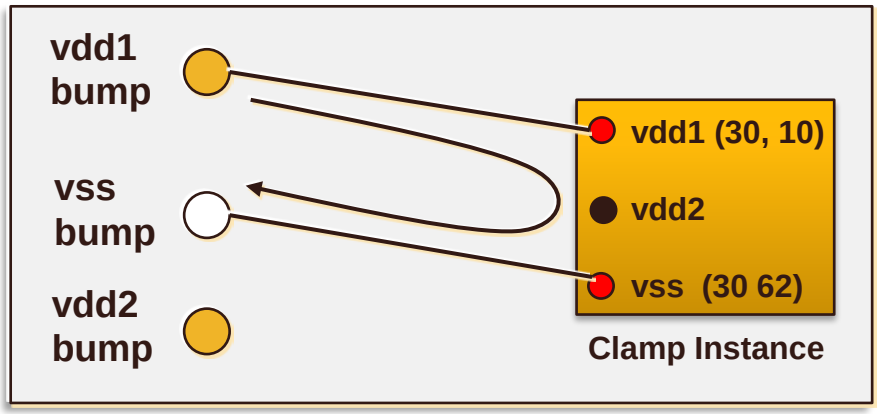


Clamp2Clamp (C2C)

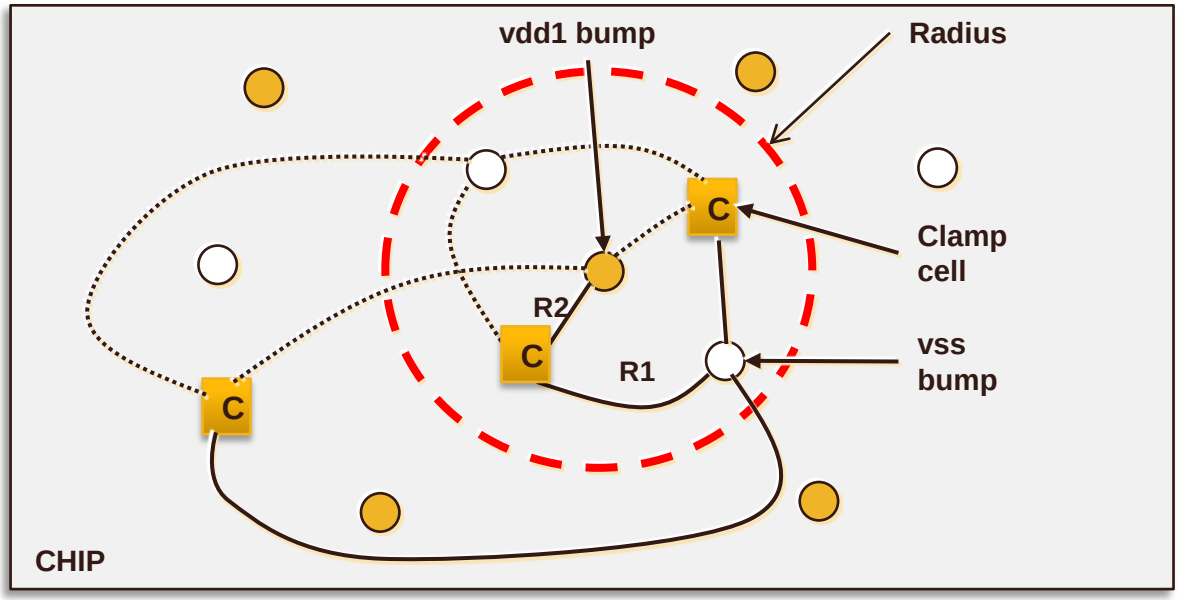


Bump2Bump_Multistage (B2BM)

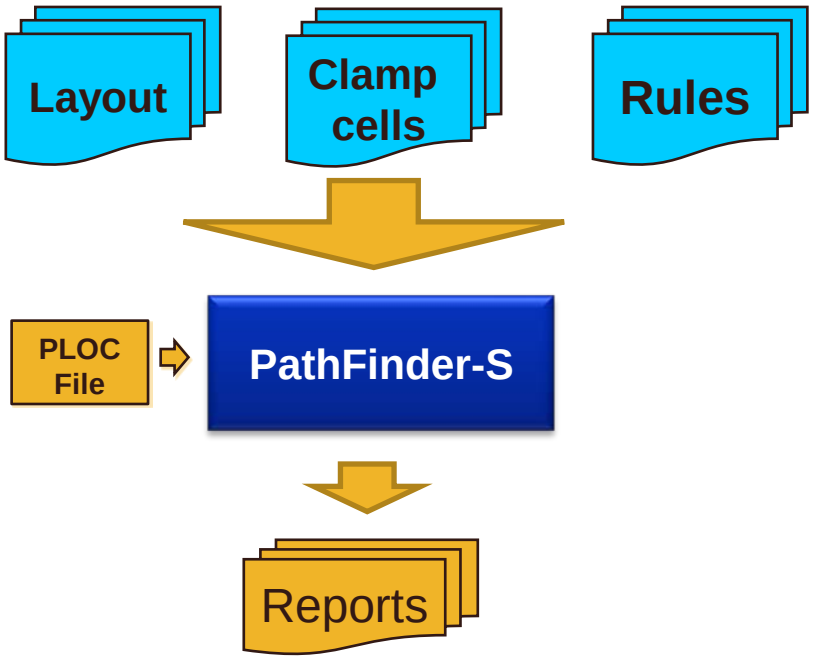
PathFinder-S HBM/MM ESD Checks – B2B Example



BUMP—CLAMP—BUMP



PathFinder-S HBM/MM ESD Check Flow



- **A** • setup design <gsr>
- **B** • perform extraction -power –ground
- **C** • perform esdcheck <options>
- **D** • Analyze results
  • (Graphical and Textual Reports)

PathFinder-S will generate violation report which the user can view in **RedHawk** GUI.

- **Floor-plan stage planning**
- **Pre-tapeout sign-off verification**

Input Data Requirements

- Design data (Provided as a **design GSR**)
  - Technology File
  - LEF/DEF Files
  - Power Domains
  - GDS2DEF views (Optional)
- ESD Rule Information (Provided as **esd rule file**)
  - Rule Name
  - Analysis Type (B2B / B2C / C2C / B2B_MULTISTAGE)
  - Thresholds (PARALLEL_R, LOOP_R, MAX_R and Radius)
- ESD Clamp Information (Provided as **clamp cell file**)
  - Node and Layer information
- PathFinder Command File

PathFinder Analysis - Command

ESD Check Command

perform esdcheck -rule <ruletype | file> -clampCell < {cell1, ..} | file> ?-radius <v1, v2> ? ?-arcR <v> ?
? -loopR <v> ? ? -parallelR <v> ? ? -excludebump <file> ? ? -bump <bump1, ..> ?
? -domain <domain1, ...> ? ?-useMin ? ?-incr ? ? -append ? ?-outdir <path> ? ? -thread <num> ?

-rule/-clamp	: Rule and Clamp File; At least one rule needs to be specified;
	<Rule_TYPE> : BUMP2BUMP (B2B), BUMP2CLAMP (B2C), CLAMP2CLAMP (C2C), or BUMP2BUMP_MULTISTAGE (B2B_MULTISTAGE or B2BM)
-radius	: radius for bump-pair formation
-arcR	: resistance threshold for B2C and C2C checks
-loopR	: resistance constraint for single bump-clamp-bump loop
-parallelR	: effective resistance constraint for parallel bump-clamp-bump paths
-excludebump	: list of bumps, one per line, to be exluded from the analysis
-bump	: list of pads to be considered for ESD analysis
-domain	: list of domains to be considered for ESD analysis
-append	: Append results to output files (instead of overwriting)
-incr[emental]	: Do incremental instance and macro point selection
-useMin	: if any B2B loop path R < parallelR skip parallel R computation
-outdir	: Save outputs to the specified directory; default: adsRpt/ESD
-thread	: Number of threads for resistance computation; default: 2

Rule file and clamp files are highly recommended in place of command line options

All arguments in ?<> ? are optional

ESD Rule File

- **ESD Rule**
  - Multiple ESD Rules (BEGIN..END) in same rule file supported

```
BEGIN_ESD_RULE

    NAME <ruleName>                          # required
    TYPE <ESD_Rule_TYPE>                     # required
    Radius <value>                           # default 500u
    PARALLEL_R <value>                       # required for B2B
    LOOP_R <value>                           # required for B2B
    ARC_R <value>                            # required for B2C, C2C
    ESD_STAGE 2                              # required for B2BM
    EXCLUDE_BUMP <bump1, bump2...>           # same as -excludebump command line
    BUMP_LIST  <bump1, bump2...>             # same as –bump command line

END_ESD_RULE
```

Note: ESD_STAGE 2 applies to B2BM. It indicates two stage of bump to bump checks (for example : bump1 -> clamp1 -> clamp2 -> bump2. PathFinder also supports 2 stage ESD checks.

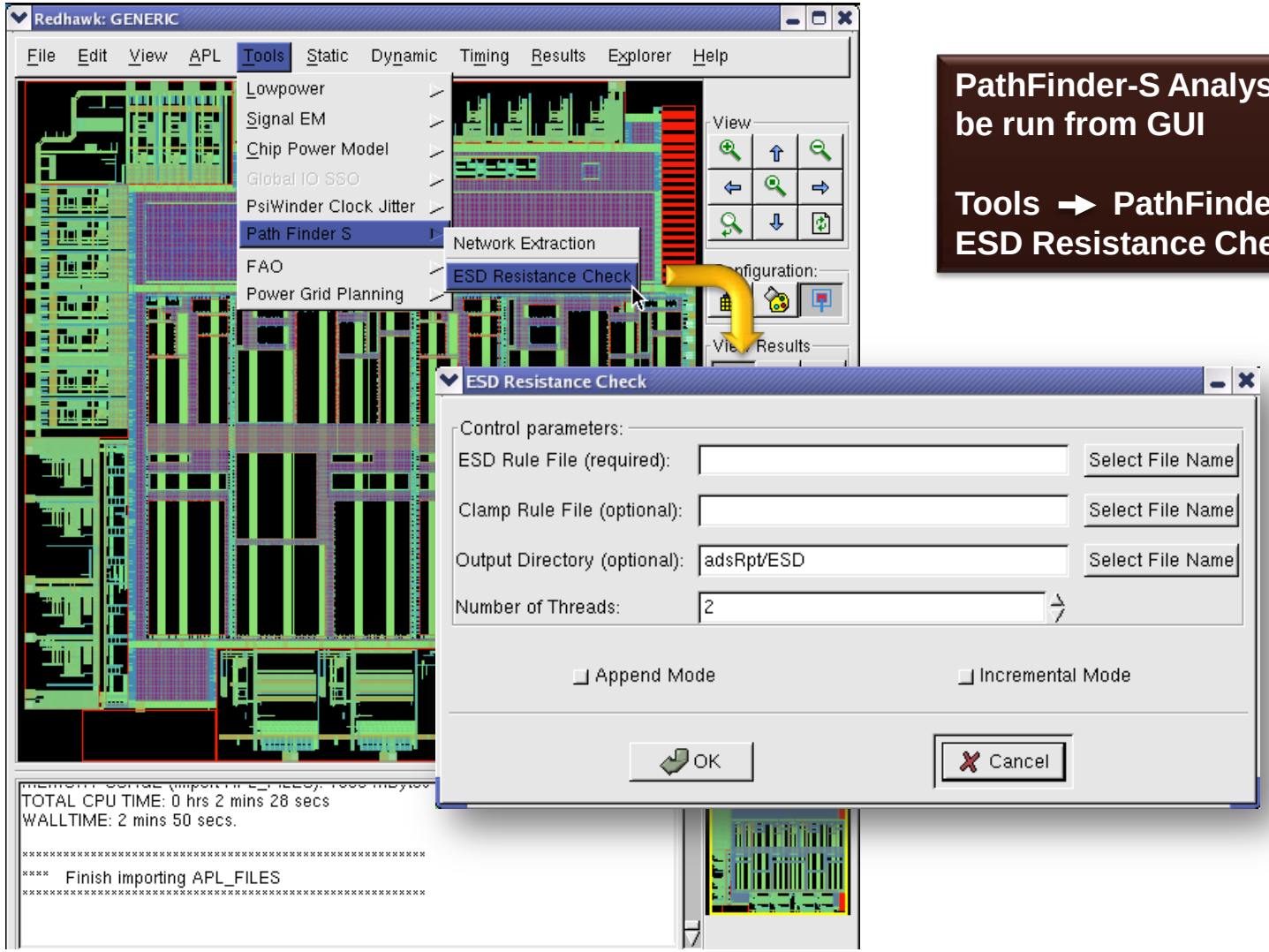
Clamp File

- **Clamp File**

```
BEGIN_CLAMP_CELL

    NAME <cellName>                  # required
    PIN <name> <x> <y> [<layer>]     # multiple ok
    PIN <name> <x> <y> [<layer>]     # multiple ok
    ESD_PIN_PAIR  <vdd> <vss>
    Ron  <n>                         # clamp On Resistance

END_CLAMP_CELL

...

# multiple clamp cell definitions ok
```

- Specify domain pairing using ESD_PIN_PAIR, if multi-rail Clamps

Run PathFinder Analysis – From GUI



PathFinder-S Analysis can also be run from GUI

Tools ➔ PathFinder-S ➔ ESD Resistance Check

PathFinder-S HBM/MM ESD Check Flow

Step 0) Get node location inside clamp cell

Step 1) Compute bump to clamp resistance

Step 2) Compute loop resistance

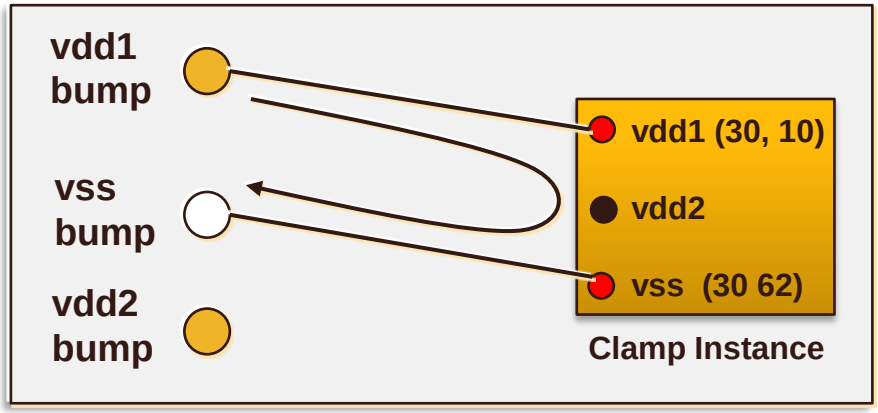
Step 3) Compute parallel resistance

PathFinder-S HBM/MM Checks

Step 0) Get node location inside clamp cell

1) From clamp cell file if it is read in:

```
BEGIN_CLAMP_CELL
NAME esd_clamp_cell1
    PIN vss  30, 62   M6
    PIN vdd1  30, 10 M5
    RON   0.01
END_CLAMP_CELL

BEGIN_CLAMP_CELL
NAME esd_clamp_cell2
    PIN vss  30, 62   M6
    PIN vdd1  30, 10 M5
    RON   0.01
END_CLAMP_CELL
```



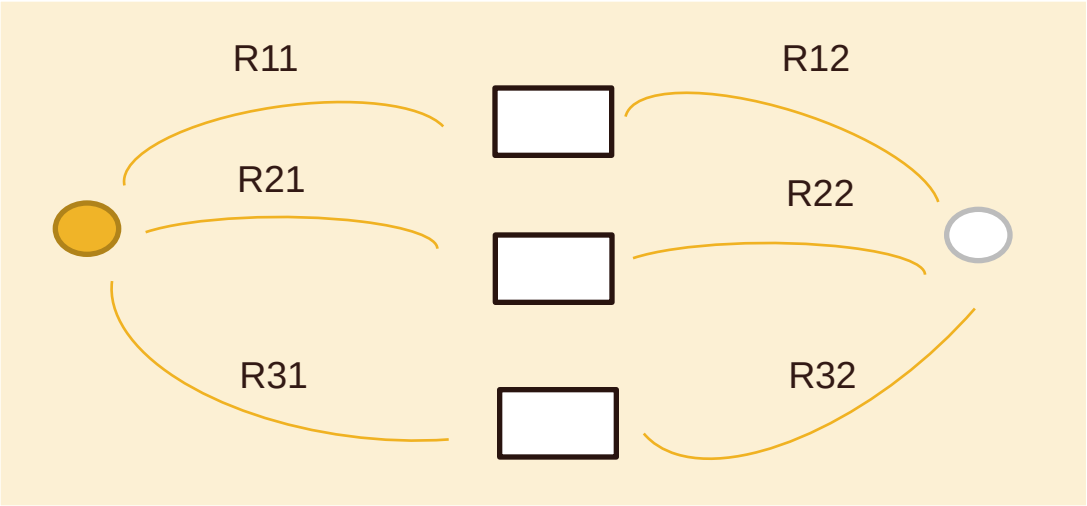
DEFINE PRIMARY POWER AND GROUND PINS FOR ESD CHECKING

```
setup design  design.gsr

perform extraction  -power  -ground

perform  esdcheck  -rule  esd.rule  -radius  {500}  -clamp clamp_cell.all   -exlude_bump
{vdd3, vdd4, vss1}  -thread 4
```

PathFinder-S HBM/MM Checks

Step 1) Compute bump to clamp resistance

Step 2) Compute loop resistance



Loop R: R11+R12

Loop R: R21+R22

Loop R: R31+R32

PathFinder-S HBM/MM Checks

Step 3) Compute parallel resistance

If any loop R < parallel_R_constraint

    Parallel_R = min{loopR}

Else

    Calculate point (bump1) to point(bump2) resistance

PathFinder-S HBM/MM Checks

Step 3) Compute parallel resistance (Example Report)

BUMP PAIR: (DVSS9 4879.91 1898.85 METAL4 VSS) <-> (DVDD12 4905.67 2198.85 METAL4 VDD)

FAIL: 3.36281 1.54069 1.82203 inst_129423/inst_92357 VSS VDD

PASS: 3.21148 1.41461 1.79677 inst_129422/inst_7773 VSS VDD

PASS: 2.42632 1.02033 1.40589 inst_129425/inst_7773 VSS VDD

PASS: 2.7599 1.2322 1.5276 inst_129424/inst_92357 VSS VDD

Loops

PARALLEL R: 1.64127

Parallel R of all loops

BUMP PAIR: (DVSS11 4879.91 2138.85 METAL4 VSS) <-> (DVDD10 4905.67 1958.85 METAL4 VDD)

FAIL: 3.3489 1.81188 1.53692 inst_129423/inst_92357 VSS VDD

PASS: 3.19746 1.68638 1.51099 inst_129422/inst_7773 VSS VDD

PASS: 2.40219 1.27426 1.12783 inst_129425/inst_7773 VSS VDD

PASS: 2.74562 1.50433 1.24119 inst_129424/inst_92357 VSS VDD

PARALLEL R: 1.62248

Pass : R < threshold

Fail : R > threshold

HBM ESD Output Files

- **Output Files in adsRpt/ESD or -outdir <>**
  - **ClampInfo.rpt**
    - **Reports clamp information**
  - **esd_summary.rpt**
    - **Contains summary of esd analysis**
  - **esd_pass.rpt**
    - **Contains passing bump to clamp or clamp to clamp results**
  - **esd_fail.rpt**
    - **Contains failing bump to clamp or clamp to clamp results**
  - **esd_info.rpt**
    - **Advanced information related to analysis**

ESD type specific reports

ESD Output File Formats

- **ClampInfo.rpt**

Rule Header

```
RULE <Rule name>(<Rule Type>):
BEGIN_ESD_RULE
  NAME <Rule name>
  TYPE [ CORE2CLAMP | CORE2CLAMP_MACRO ]
  INST_COUNT  <#instances>
  ARC_R  <value in ohms>
  LOOP_R <value in ohms>
END_ESD_RULE
```

Clamp Cell Information

```
CLAMP CELL INFO:
BEGIN_CLAMP_CELL
  NAME <Clamp Cell Name>
  PIN <pin name> <node x y> <layer>
  RON <R Value in Ohms>
END_CLAMP_CELL
```

Clamp Instance Information

```
CLAMP CELL: <Clamp Cell Name> {
  <INSTANCE> <X1 Y1 X2 Y2> <ORIENT>
  <XY LOCATION> <LAYER> <NET> <PIN> [<locID>]
}
```

ESD Output File Formats – B2B

- **esd_summary.rpt**

  - **Provides summary of B2B Checks**

  Rule Header

  Domain pair <id>: (<net1> <net2>) {
  Clamp connections between (<net1> <net2>): <#>
  Bump-to-bump pairs checked: <#>
  Bump-to-bump loop resistances:
  Pass: <#> (% of <total>)
  Fail: <#> (% of <total>)
  Bump-to-bump parallel resistances:
  Pass: <#> (% of <total>)
  Fail: <#>(% of <total>)
  }

- **esd_info.rpt**

  - **Lists Bumps per domain for each domain pair**

  Rule header

  Domain pair <id>: (<net1> <net2>) {
  Bump pairs checked: <#>
  Bump list for domain <net1> (<#>) {
  <bump_list1> (<name> <xy_loc> <layer> <net>)
  }
  Bump list for domain <net2> (<#>) {
  <bump_list2> (<name> <xy_loc> <layer> <net>)
  }
  }

- **esd_pass.rpt / esd_fail.rpt**

  - **Lists passing and failing bump to bump loops**

  Rule header

  Bump pair: (<BUMP1> <X> <Y> <LAYER> <NET>) (<BUMP2> <X> <Y> <LAYER> <NET>)
  Pass/fail: <loop_r> <arc1_r> <arc2_r> <clamp> <locid1> <locid2>
  Parallel r: <value>

ESD Output File Formats – B2C

- **esd_summary.rpt**

  - **Provides summary of B2C Checks**

  Rule Header

  Clamp cell count: <#>
  Clamp instance count: <#>
  Bump point count: <#>

  Per NET : bump, clamp and bump to clamp path summary

  Resistance and pass/fail summary

```
Bump-to-clamp R check summary for rule <rules1> (BUMP2CLAMP):
 Clamp cell count: 1
 Clamp instance count: 4
 Bump point count: 80

 Group  Net    Bumps   Clamps  Resistances
 ------------------------------------------------
 1      VSS    40      4       160
 2      VDD    40      4       160
 ------------------------------------------------
        Total  80      8       320

 Rule: 1.5 Ohms, Min: 0.864704 Ohms, Max: 4.65652 Ohms
 Fail count: 280 (87.50% of 320)
 Pass count: 40 (12.50% of 320)
```

- **esd_pass.rpt / esd_fail.rpt**

  - **Lists passing and failing bump to clamp paths**

  Rule header

  Bump: <x> <y> <layer> <net> <bump_name>
  <R> <X> <Y> <LAYER> <NET> <locid> <CLAMP_INST>

ESD Output File Formats – C2C

- **esd_summary.rpt**

  - **Provides summary of C2C Checks**

  Rule Header

  Clamp cell count: <#>
  Clamp instance count: <#>

  Per NET : clamp and clamp to clamp path summary

  Resistance and pass/fail summary

```
Clamp-to-clamp R check summary for rule <rules1>
(CLAMP2CLAMP):
 Clamp cell count: 1
 Clamp instance count: 4

 Group  Net     Points  Resistances
 ------------------------------------------------
 1      VSS     4       6
 2      VDD     4       6
 ------------------------------------------------
        Total   8       12

 Rule: 1.2 Ohms, Min: 1.45462 Ohms, Max: 1.9556 Ohms
 Fail count: 12 (100.00% of 12)
 Pass count: 0 (0.00% of 12)
```

- **esd_pass.rpt / esd_fail.rpt**

  - **Lists passing and failing clamp to clamp paths**

  Rule header

  Clamp point: <x> <y> <layer> <net> <locid> <clamp_inst>
  <R> <X> <Y> <LAYER> <NET> <locid> <CLAMP_INST>

ESD Output File Formats – B2BM

- **esd_summary.rpt**

  - **Provides summary of B2B Checks**

  Rule Header

  Domain pair <id>: (<net1> <net2>) {
  Internal domain: <net>
  Clamp connections to <net1> : <#>
  Clamp connections to <net2> : <#>
  Direct clamp connections between (<net1> <net2>): 0
  Bump-to-bump pairs checked: <#>
  Bump-to-bump loop resistances:
  Pass: <#> (% of <total>)
  Fail: <#> (% of <total>)
  Bump-to-bump parallel resistances:
  Pass: <#> (% of <total>)
  Fail: <#>(% of <total>)
  }

- **esd_info.rpt**

  - **Lists Bumps per domain for each domain pair**

  Rule header

  Domain pair <id>: (<net1> <net2>) {
  Internal domains: <num>
  <Net_names>
  Bump pairs checked: <num>
  Bump list for domain <net1> (<#>) {
  <bump_list1> (<name> <xy_loc> <layer> <net>)
  }
  Bump list for domain <net2> (<#>) {
  <bump_list2> (<name> <xy_loc> <layer> <net>)
  }
  }

- **esd_pass.rpt / esd_fail.rpt**

  - **Lists passing and failing bump to bump loops**

  Rule Header

  Bump pair: (<bump1> <x> <y> <layer> <net>) (<bump2> <x> <y> <layer> <net>)
  Pass/fail: <loop_r> <arc1_r> <arc2_r> <clamp> <locid1> <locid2> <int_net> <clamp> <locid3> <locid4>
  Parallel r: <value>

HBM Analysis – Hands-On Training Testcase

Download Testcase

- **Generic testcase**
  - **Download instructions**

```
% ftp ftp.apache-da.com
Name: anonymous
Password: <your email address>
ftp> cd outgoing
ftp> get GENERIC_tutorial.tar.gz
ftp> bye
```

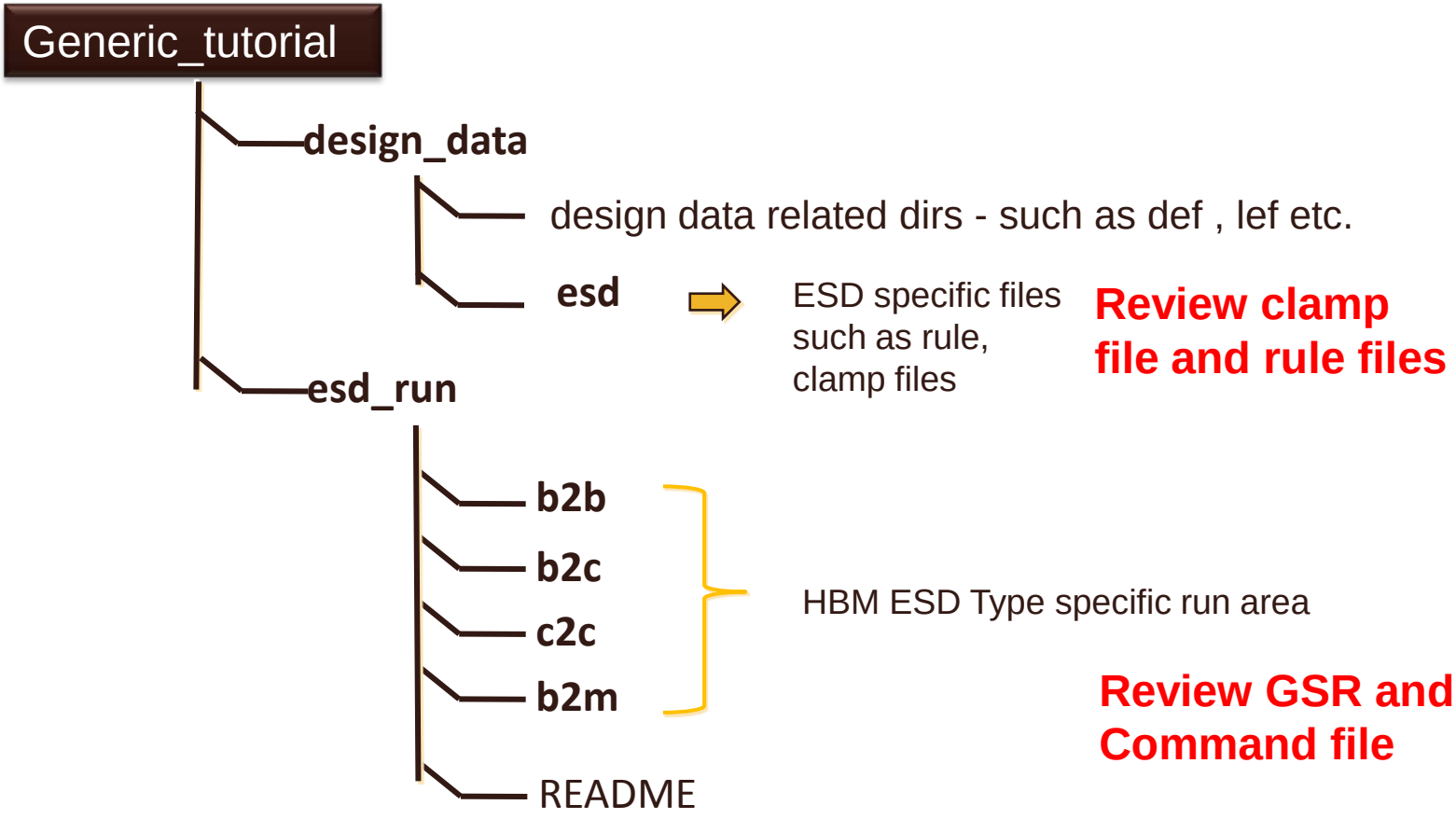
  - **Untar testcase**

```
% cd <work_area>
% gtar –zxvf GENERIC_tutorial.tar.gz
% \rm GENERIC_tutorial.tar.gz
% cd GENERIC_tutorial.tar.gz/
% more README
```

Approximately 0.5GB space is required for testcase

Directory Structure

- **Directory structure in <work_area>/Generic_tutorial/esd_run**



Run PathFinder Analysis

- **Clamp file is common to all analysis**
- **Rule file is specific to the ESD analysis (./design_data/esd/)**

```
BEGIN_CLAMP_CELL
NAME cell_10
  PIN VSS 10, 68 METAL4
  PIN VDD 10, 73 METAL4
  ESD_PIN_PAIR VDD VSS
  RON 0.0001
END_CLAMP_CELL
```

Clamp File

```
BEGIN_ESD_RULE
NAME        rules1
TYPE        B2B
RADIUS      500
LOOP_R      3.25
PARALLEL_R  1.5
END_ESD_RULE
```

Rule file for B2B

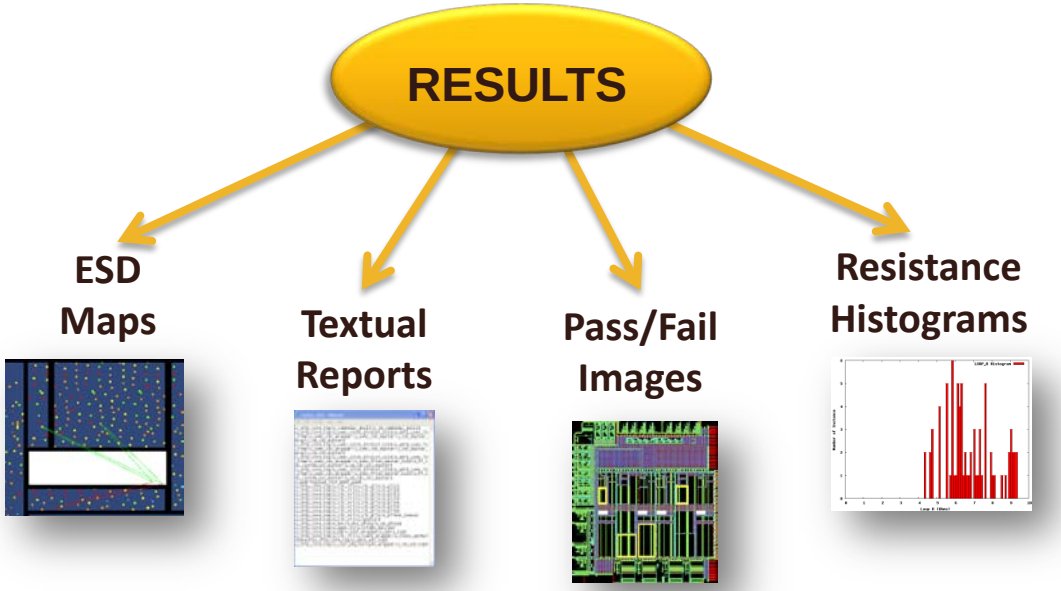
- **Run ESD analysis**

```
> cd  b2b                          #  go to esd analysis specific run area
> RedHawk  -f   run_b2b.tcl  &     #  run analysis
```

Result Analysis (HBM)

- **Check HBM results in adsRpt/ESD/**
- **Displaying Loop/Parallel Path Resistance Histograms**
- **Displaying Topology Checking Results in the GUI**

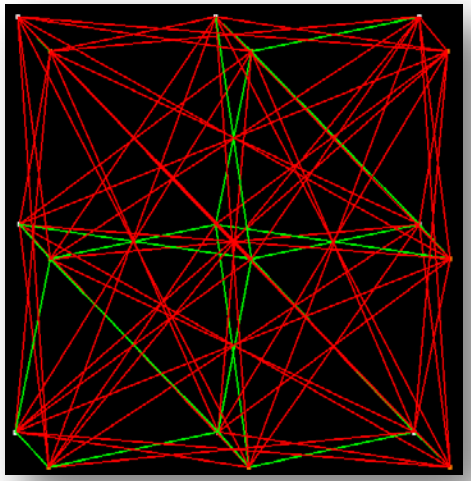
See PathFinder-S utilities on subsequent slides for HBM analysis



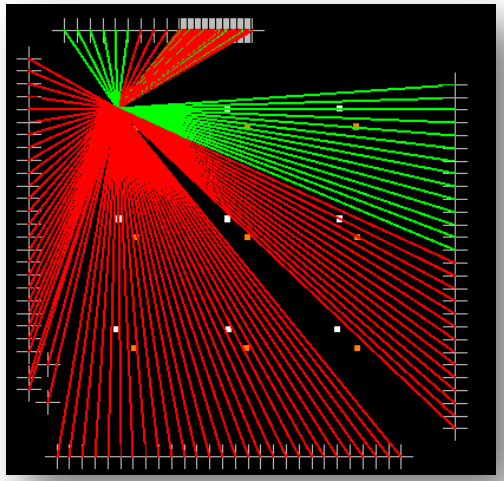
Displaying results in GUI

- **atclDisplayRes.tcl displays passing and failing bump to clamp or bump to bump color-coded paths**
  - **Source the script in RedHawk session**
    > source <script_path/atclDisplayRes.tcl>
    (Build scripts get sourced automatically)
  - **Run the script**
    > atclDisplayRes –h # for list of all options

Script supports resistance path display for all HBM ESD types : B2B, B2C, C2C



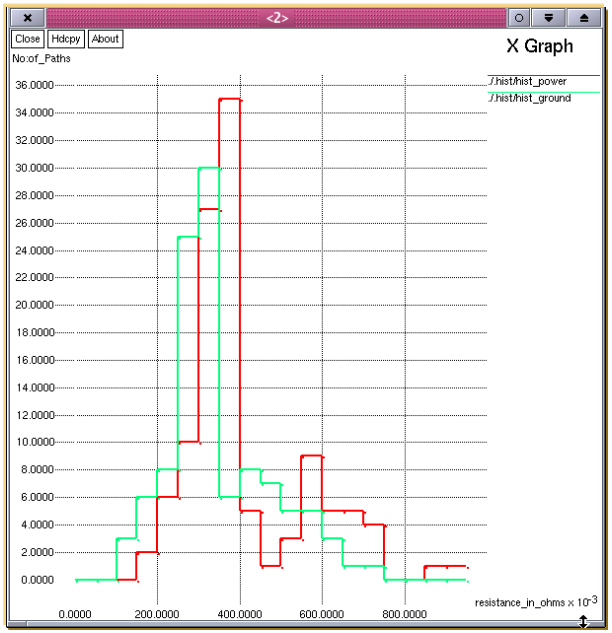
Displaying all B2B paths (passing and failing)



Displaying paths from specific bump to all connected clamps

Displaying results in GUI

- **atclResHisto.tcl plots loop/parallel path resistance histograms**
  - **Source the script in RedHawk session**
    > source <script_path/atclResHisto.tcl>
  - **Run the script**
    > atclResHisto –h # for list of all options



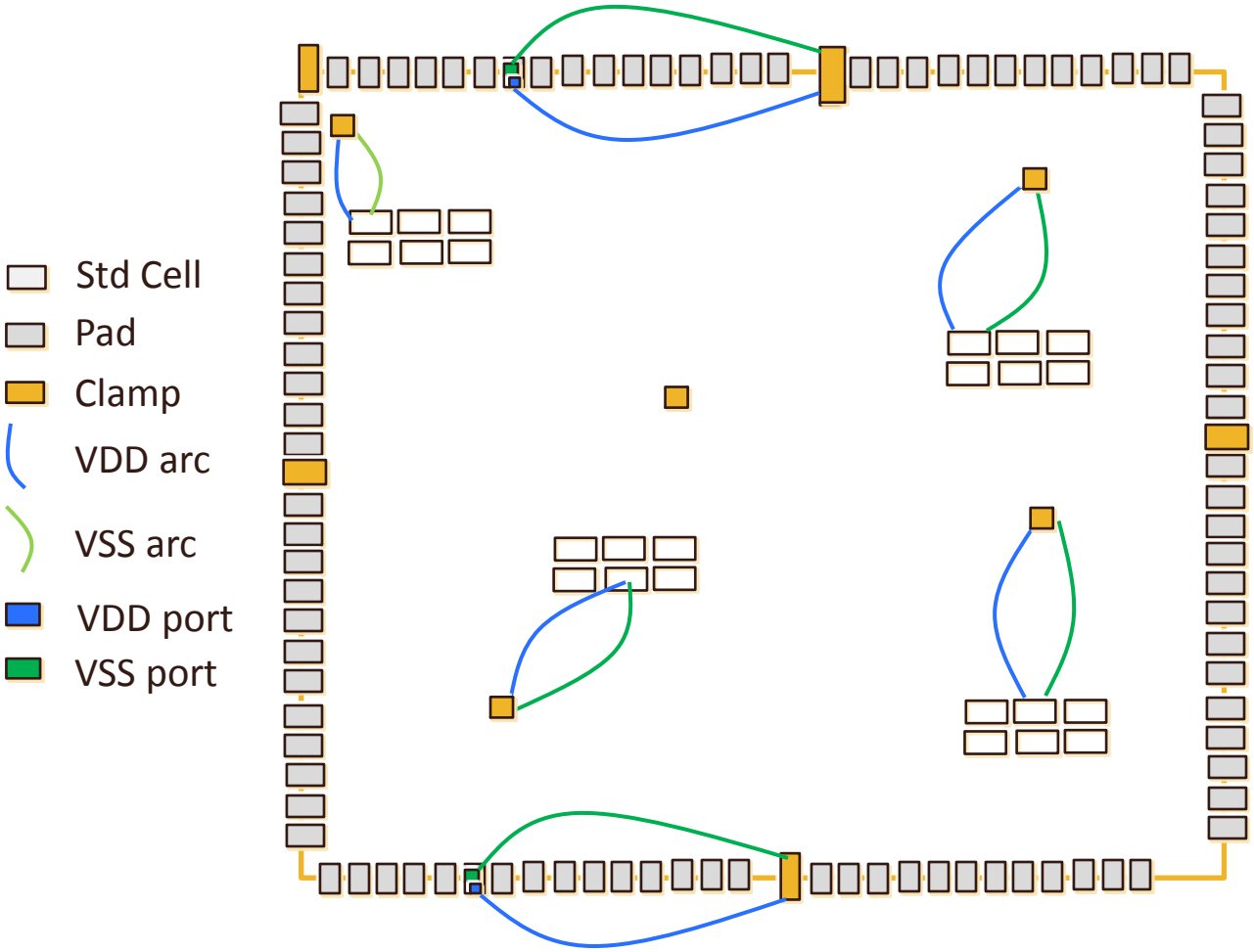
Script supports resistance path display for all HBM ESD types : B2B, B2C, C2C

Red and Green shows the passing and failing resistance path histograms

Section - IV

PathFinder-S™ CDM ESD Analysis

Standard Cell/PAD ESD Checks



For every instance:

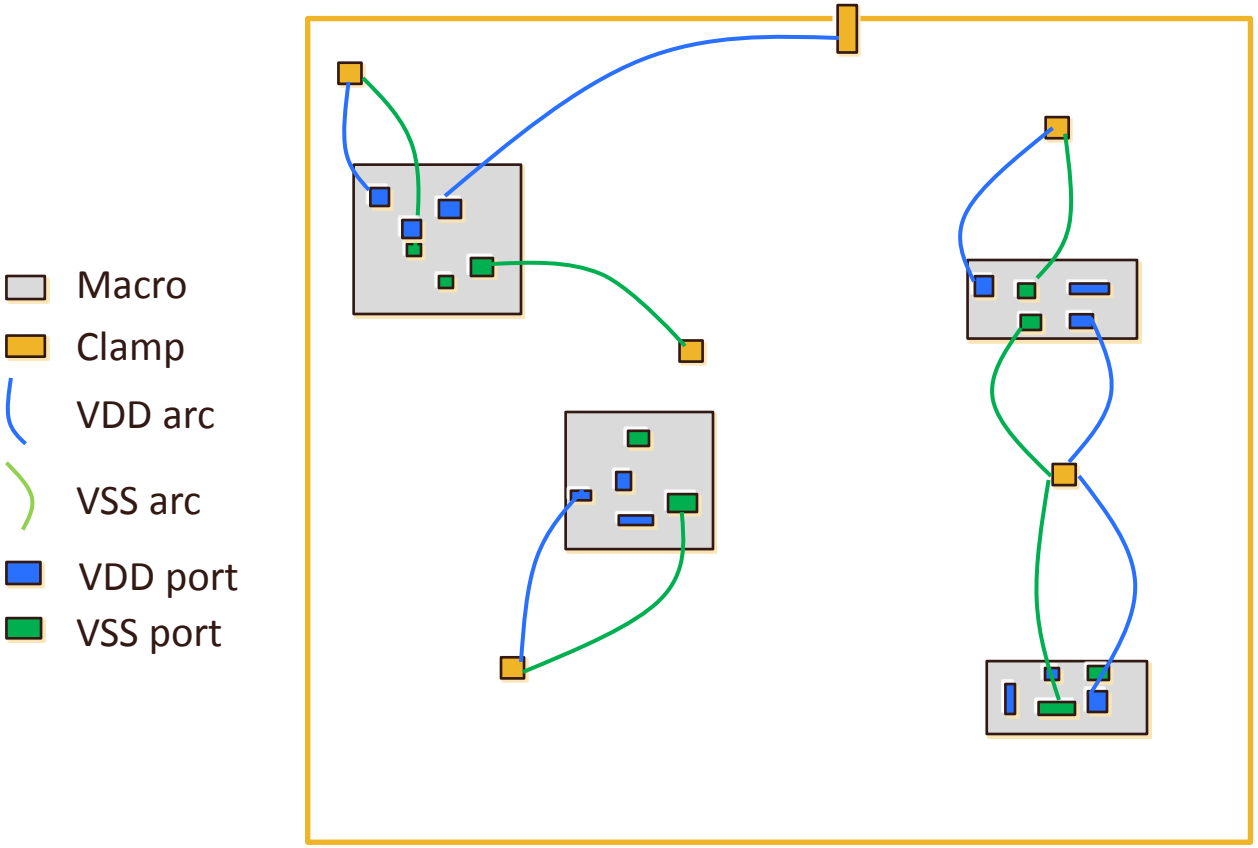
1) Calculate loop resistances w.r.t each clamp cell

2) If one loop passes, then instance passes ESD check

Figure only shows one loop resistance per instance

All loops are calculated in PathFinder

Macro ESD Checks



For every macro port:

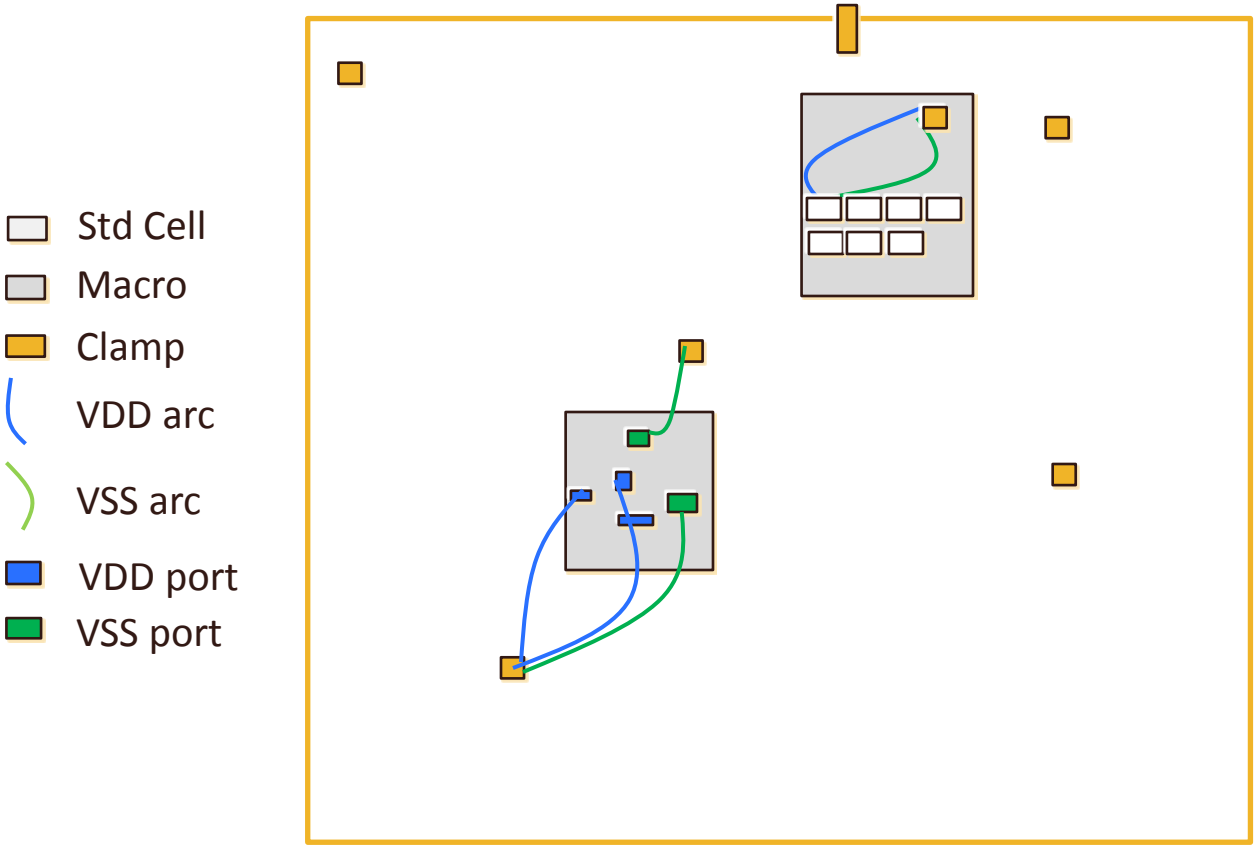
1) Calculate all arc resistances

2) If all arc passes, then macro port passes ESD check

Figure only shows one arc resistance per macro port

All arcs are calculated in PathFinder (i.e., arcs w.r.t all clamps in design)

Analog Macro ESD Checks



Verify:
(1) Macro ports
(2) Std. cells inside macro

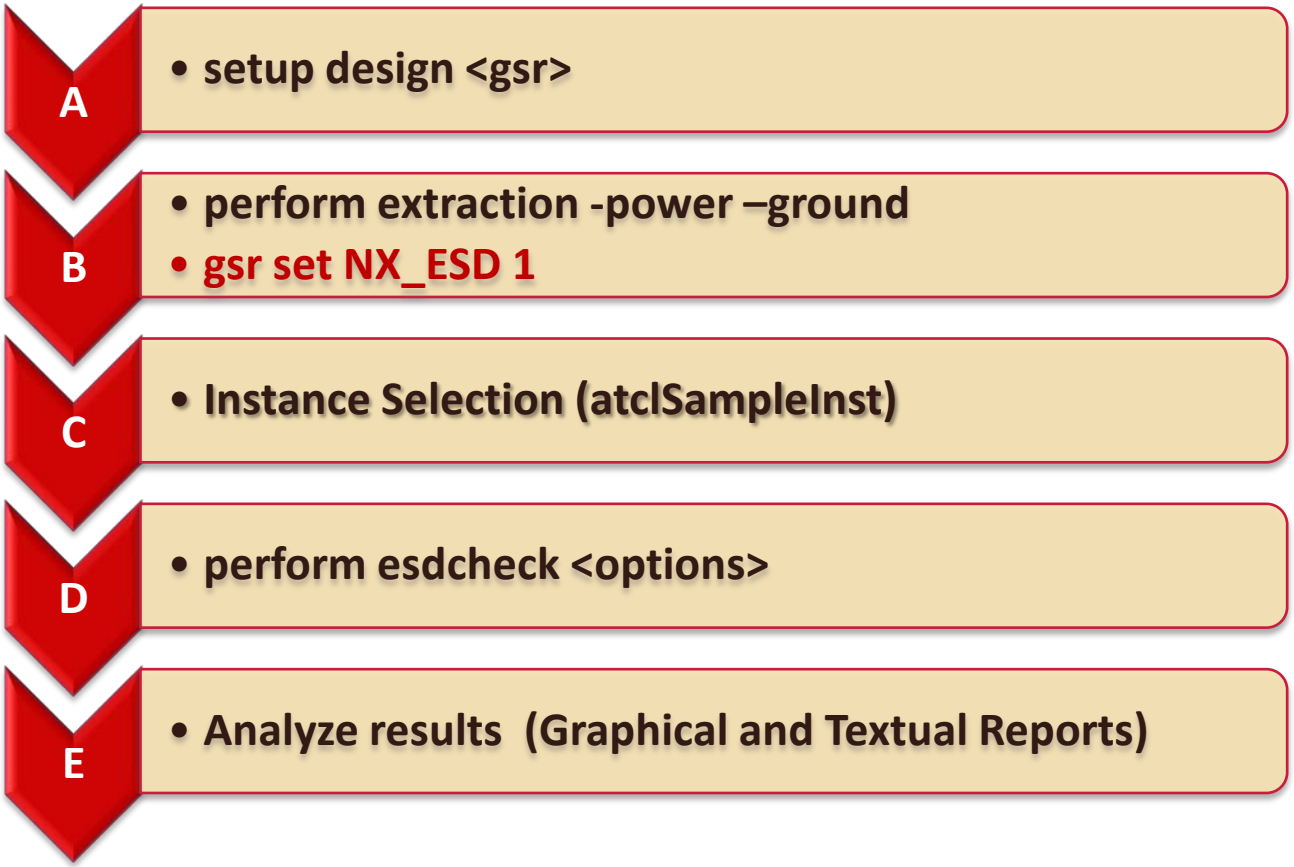
For every analog macro with std. cells:

1) Calculate all loop resistances for every std. cell inside macro

2) Calculate all arc resistances for every port of macro

Figure only shows one arc resistance per macro port and one loop resistance per std. cell
All loops and arcs are calculated in PathFinder (i.e., loops/arcs w.r.t all clamps in design)

PathFinder-S (PFS) CDM ESD Flow



Input Data Requirements

- Design data (Provided as a **design GSR**)
  - Technology File
  - LEF/DEF Files
  - Power Domains
  - GDS2DEF views (Optional)
- ESD Rule Information (Provided as **esd rule file**)
  - Rule Name
  - Analysis Type (C2I or C2M)
  - Resistance Thresholds (ARC_R and LOOP_R)
- ESD Clamp Information (Provided as **clamp cell file**)
  - Node and Layer information
- List of Instances to be verified for ESD protection
- PathFinder Command File

How to Select Instances for ESD Analysis?

- Instance selection done using atclSampleInst tcl Script.
- Grid based sampling ensures uniform distribution
- Make utility generates necessary parameters for this script based on ESD configuration file information

atclSampleInst.tcl [arguments]

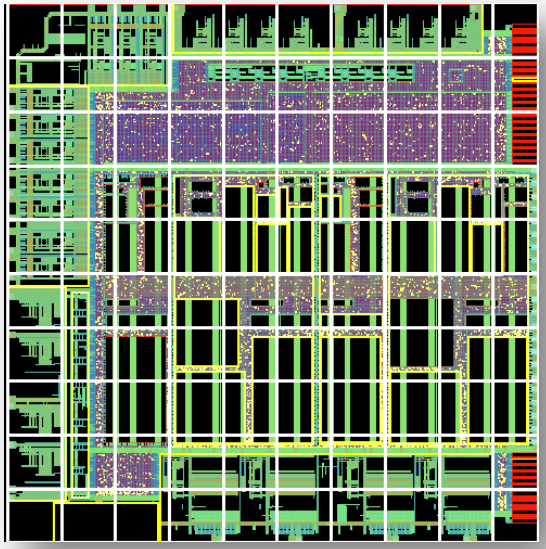
Arguments:

```
-n <% value>          # %instances to be picked from each grid(applies when –xrange and –yrange specified)
-xrange <value>       # Grid width (Default:  500u)
-yrange <value>       # Grid height (Default:  500u)
-o <output_file>      # Specify the output file name
-max_limit <#>        # Max cap on selected instance count
-type <INST|MASTER>   # Instance or master cell name based pattern matching
-include <pattern_file>   # Include instances matching this pattern. Pattern file contains one pattern per line.
-exclude <pattern_file>  # Exclude instance matching this pattern. Pattern file contains one pattern per line.
[-h]                  # Command usage
[-man]                # Man page
```

How to Select Instances for ESD Analysis? (Contd..)

- Divides the die in number of grids; Selects n% of instances from each grid.
- MAX_LIMIT puts upper limit on selected instances.
- Instance selection can further be refined by INCLUDE and EXCLUDE pattern list. Instances will be selected based on Instances or master cells matching the INCLUDE pattern and not matching the EXCLUDE pattern list.
- The atclSampleInst tcl script can select following types of instances
  - Standard Cells (Logic cells, Level Shifters, Tap Cells etc)
  - PAD Cells
  - Memory Macros
  - Custom Macros
  - Standard Cells inside Custom Macro

Do not specify X and Y range to select Pad, Memory and Custom Macros



Uniform grid sampling for instances

ESD Check Command

- **ESD Check Command**

perform esdcheck -rule <file> ?-clamp <file>? ?-instfile <file>? ?-append? ?-incr?
?-mcore <num>? ?-outdir <path>? ?-reportArc? ?-sampleInst <num>?
?-samplePoint <num>? ?-thread <num>? ?-verbose?

-rule/-clamp	:	Rule and Clamp File; At least one rule needs to be specified;
-instfile	:	Specify file that has core instance names in it
-append	:	Append results to output files (instead of overwriting)
-incr[emental]	:	Do incremental instance and macro point selection
-mcore	:	Number of CPU for each thread; default 0 (all CPUs)
-outdir	:	Save outputs to the specified directory; default: adsRpt/ESD
-reportArc	:	Also report Arc R check results for C2I check
-sampleInst <n>	:	Sample rate for core instances selection in percentage
-samplePoint <n>	:	Sample rate for macro point (node) selection in percentage
-thread	:	Number of threads for resistance computation; default: 2
-verbose	:	Save all resistance computation results in <outDir>/esd_info.rpt

ESD Rule File

- **ESD Rule**
  - Provides Multiple Ways to select Clamp/Core Instances
  - Allow instance selection or macro node selection control
  - Multiple ESD Rules (BEGIN..END) in same rule file supported

```
BEGIN_ESD_RULE

    NAME <ruleName>                          # required
    TYPE [CLAMP2INST|CLAMP2MACRO]            # required
    ARC_R <value>                            # one of ARC_R &
    LOOP_R <value>                           # LOOP_R is required
    LAYER <TOP|BOTTOM|layer>                 # for CORE2MACRO only (Optional)
                                               nodes will be selected only either
                                               on top / bottomo or specified layer

    .....

END_ESD_RULE
```

ESD Rule File contd…

- **ESD Rule**

```
BEGIN_ESD_RULE

    ...

    DOMAIN <net>|{<net1 net2 ...>}      # specify domains to analyze
    CLAMP <cell_name|cell_namelist>     # specify clamp cell or list
    AREA <llx> <lly> <urx> <ury>        # get core insts in a bbox
    CLAMP_AREA <llx> <lly> <urx> <ury>  # get clamp insts in a bbox
    CLAMP_INST_FILE <file|filelist>     # for clamp insts, multiple ok
    CLAMP_INST_NAME <name|namelist>     # for clamp insts, multiple ok
    INST_FILE <file|filelist>           # for core insts, multiple ok
    INSTANCE <name|namelist>            # for core insts, multiple ok
    SAMPLE_INST <num>                   # core inst sample percentage
    SAMPLE_POINT <num>                  # macro node sample percentage

END_ESD_RULE
```

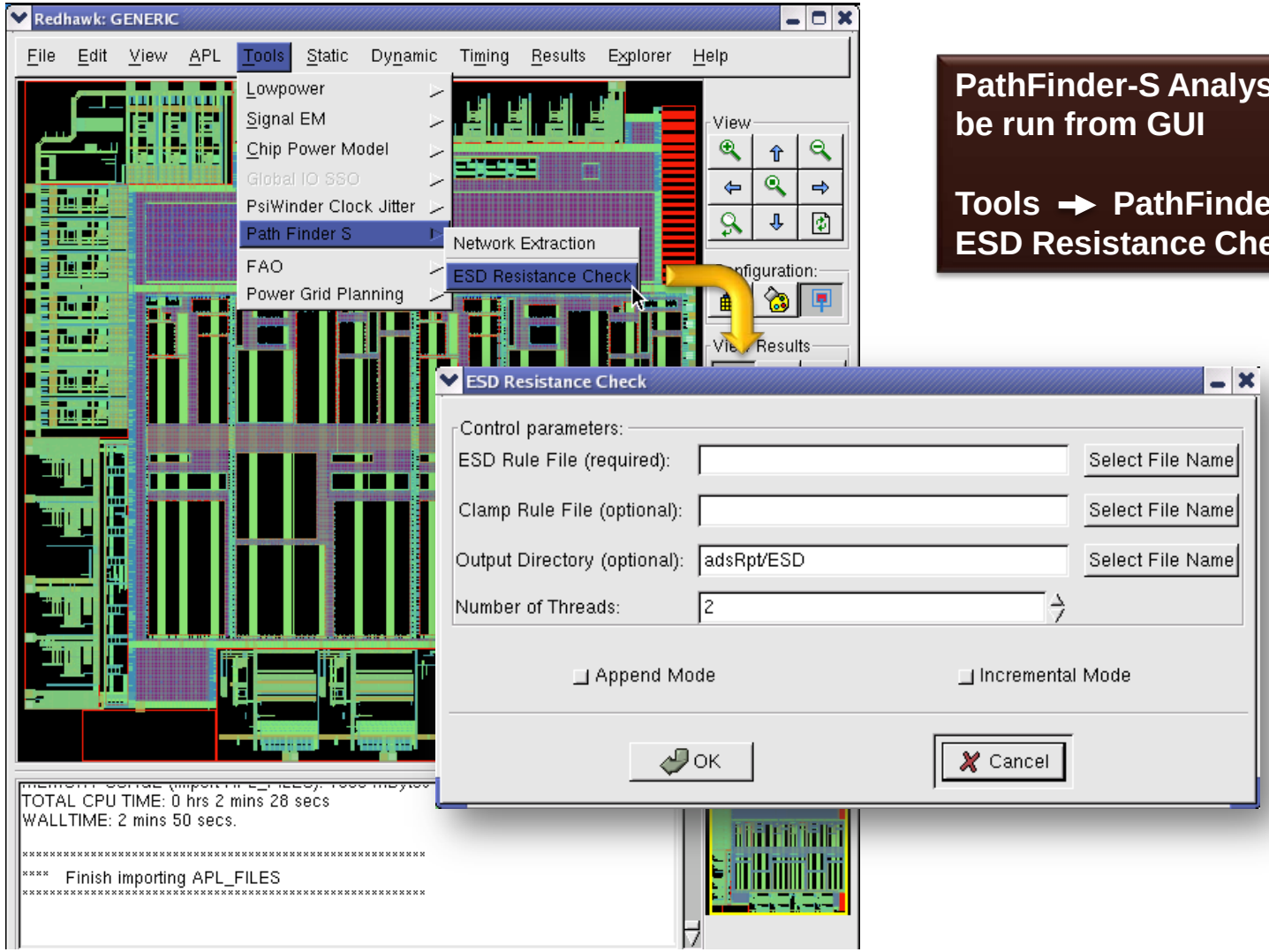
Clamp File

- **Clamp File**

```
BEGIN_CLAMP_CELL

    NAME <cellName>                  # required
    PIN <name> <x> <y> [<layer>]  # multiple ok
    PIN <name> <x> <y> [<layer>]  # multiple ok
    PIN NA <x> <y> {BOTTOM|TOP|<layerName>} # for nonLEF pin based nodes
    ESD_PIN_PAIR  <vdd> <vss>
    Ron  <n>                         # clamp On Resistance

END_CLAMP_CELL

...

# multiple clamp cell definitions ok
```

- Specify domain pairing using ESD_PIN_PAIR, if multi-rail Clamps

Run PathFinder Analysis – From GUI



PathFinder-S Analysis can also be run from GUI

Tools ➔ PathFinder-S ➔ ESD Resistance Check

ESD Output Files

- **Output Files in adsRpt/ESD or -outdir <>**
  - **ClampInfo.rpt**
    - **Reports clamp information**
  - **esd_summary.rpt**
    - **Contains summary of esd analysis**
  - **esd_pass.rpt**
    - **Contains passing Loop R results for C2I and Passing Arcs for C2M**
  - **esd_fail.rpt**
    - **Contains failing Loop R results for C2I and failing Arcs for C2M**
  - **esd_info.rpt**
    - **Contains ARC R results for all nodes**

ESD Output File Formats

- **ClampInfo.rpt**

Rule Header

```
RULE <Rule name>(<Rule Type>):
BEGIN_ESD_RULE
  NAME <Rule name>
  TYPE [ CLAMP2INST | CLAMP2MACRO ]
  INST_COUNT  <#instances>
  ARC_R  <value in ohms>
  LOOP_R <value in ohms>
END_ESD_RULE
```

Coverage Information

```
COVERAGE INFO:
Coverage area: LLx LLy URx URy
Number of instances: <#instances>
Number of selected instances: <#selected instances>
Number of valid instances: <#analyzed instances>
```

Clamp Cell Information

```
CLAMP CELL INFO:
BEGIN_CLAMP_CELL
  NAME <Clamp Cell Name>
  PIN <pin name> <node x y> <layer>
  RON <R Value in Ohms>
END_CLAMP_CELL
```

Clamp Instance Information

```
CLAMP CELL: <Clamp Cell Name> {
  <INSTANCE> <X1 Y1 X2 Y2> <ORIENT>
  <XY LOCATION> <LAYER> <NET> <PIN> [<locID>]
}
```

ESD Output File Formats

- **esd_summary.rpt**

  Reports number of pass and fail loop and arc R and corresponding %.

Rule Header ⟶

```
RULE <Rule name>(<Rule Type>):
BEGIN_ESD_RULE
  NAME <Rule name>
  TYPE [ CLAMP2INST | CLAMP2MACRO ]
  INST_COUNT  <#instances>
  ARC_R  <value in ohms>
  LOOP_R <value in ohms>
END_ESD_RULE
```

Total number of instances checked: <#instance>

loop-R: pass <#> (X%), fail <#> (X%)

arc-R: pass <#> (X%), fail <#> (X%)

ESD Output File Formats

- **esd_pass.rpt (C2I | CLAMP2INST Type)**

  Reports loops for passing instances

Rule Header →

```
RULE <Rule name>(<Rule Type>):
BEGIN_ESD_RULE
  NAME <Rule name>
  TYPE [ CLAMP2INST | CLAMP2MACRO]
  INST_COUNT  <#instances>
  ARC_R  <value in ohms>
  LOOP_R <value in ohms>
END_ESD_RULE
```

```
# LOOP_R Pass and ARC_R Pass Report: <#> instance(s)

# <LOOP_R> <ARC_R> <XY LOCATION> <LAYER> <DOMAIN> <PIN> <ARC_R> <XY
LOCATION> <LAYER> <DOMAIN> <PIN> <INST> <CLAMP> <DIST>

...

# LOOP_R Pass and ARC_R Fail Report: <#> instance(s)

# <LOOP_R> <ARC_R> <XY LOCATION> <LAYER> <DOMAIN> <PIN> <ARC_R> <XY
LOCATION> <LAYER> <DOMAIN> <PIN> <INST> <CLAMP> <DIST>

...
Summary for rule <Rule name> (Rule Type):
    loop-R pass <#> (X%)
    arc-R pass <#> (X%)
```

ESD Output File Formats

- **esd_fail.rpt (C2I | CLAMP2INST Type)**

  Reports loops for failing instances

```
Rule Header

# LOOP_R Fail and ARC_R Fail Report: <#> instance(s)
# <LOOP_R> <ARC_R> <XY LOCATION> <LAYER> <DOMAIN> <PIN> <ARC_R> <XY
LOCATION> <LAYER> <DOMAIN> <PIN> <INST> <CLAMP> <DIST>
...
# Missing P/G Connection Report: <#> instance(s)
# <LOOP_R> <ARC_R> <XY LOCATION> <LAYER> <DOMAIN> <PIN> <ARC_R> <XY
LOCATION> <LAYER> <DOMAIN> <PIN> <INST> <CLAMP> <DIST>
...
Summary for rule <Rule name> (Rule Type):
    loop-R failure <#> (X%)
    arc-R failure <#> (X%)
```

ESD Output File Formats

- **esd_pass.rpt and esd_fail.rpt (C2M | CLAMP2MACRO Type)**

  Reports passed and failed arcs in esd_pass and esd_fail respectively.

```
Rule Header

# INST <NAME> <X1 Y1 X2 Y2> <NUM_ARCS> <NUM_PASSED_ARCS>
<NUM_FAILED_ARCS>

# <ARC_R> <XY LOCATION> <LAYER> <DOMAIN> <PIN> <CLAMP> <XY LOCATION>
<LAYER>

...


Summary: Rule <Rule name> (Rule Type): <#(passed | failed) arcs>/<#arcs>
(passed | failed) arc-R check (X%)
```

ESD Output File Formats

- **esd_info.rpt**

```
# Starting point: (x1 y1 Layer Domain) Clamp
# Ohm   Location(x y)  Layer   Net     Instance
   <val>  (x2 y2)   Layer   Net     Instance
```

Example:

```
# Starting point: (4521.65 2201.16 METAL4 VSS) inst_129425/inst_7773
# Ohm   Location(x y)   Layer   Net     Instance
18.591  571.26  4108.01 METAL3  VSS     inst_129539/adsU1
...
```

This shows the VSS arc from (4521.65, 2201.16) metal4 on clamp inst_129425/inst_7773 to (571.26, 4108.01) metal3 on instance inst_129539/adsu1. The resulting arc resistance is 18.591 ohms.

Notes:

- esd_info.rpt contains arc resistance computation results for all the arcs from instance to clamp.
- All the arcs are reported to esd_info.rpt, only if verbose mode is enabled.
  `perform esdcheck -rule <esd_rule_file> -clamp <clamp_file>  -verbose`
- The pass/fail report contains only the electrically shortest arcs, all other arcs from instance to clamp would be reported to esd_info.rpt

ESD Output File Formats

- **Report Format for Multiple ESD rules in single rule file**

esd.rule file

```
BEGIN_ESD_RULE
NAME        esd_rule_1
TYPE        Rule_Type
ARC_R       1
LOOP_R      2
END_ESD_RULE

BEGIN_ESD_RULE
NAME        esd_rule_2
TYPE     Rule_Type
ARC_R       10
LOOP_R      20
SAMPLE_INST 12000
CLAMP_INST_FILE
clamp_insts.list
END_ESD_RULE
```

reports

```
Rule1 header

#Loop/ARC results for C2I/C2M

Rule2 header

#Loop/ARC results for C2I/C2M

Summary
```

The formats for all reports is same. The results corresponding to each rule would follow the rule header as defined in the esd.rule file.

Usage Example

perform esdcheck -clamp clamp.info -rule c2i.rules1

perform esdcheck -clamp clamp.info -rule c2i.rules2 - append

perform esdcheck -clamp clamp.info -rule c2i.rules3 -outdir adsRpt/ESD_rules3_results

Append Resuts

Rule file : c2i.rules1

```
BEGIN_ESD_RULE
  NAME c2i_std
  TYPE   CLAMP2INST
   INST_FILE  std1.list
   ARC_R    1
   LOOP_R   2
END_ESD_RULE

BEGIN_ESD_RULE
  NAME c2i_pad
  TYPE   CLAMP2INST
   INST_FILE  pad1.list
   ARC_R    1.5
   LOOP_R   3
END_ESD_RULE
```

Output in adsRpt/ESD

esd_summary.rpt
esd_pass.rpt
esd_fail.rpt
ClampInfo.rpt

Output in adsRpt/ESD_rules3_results

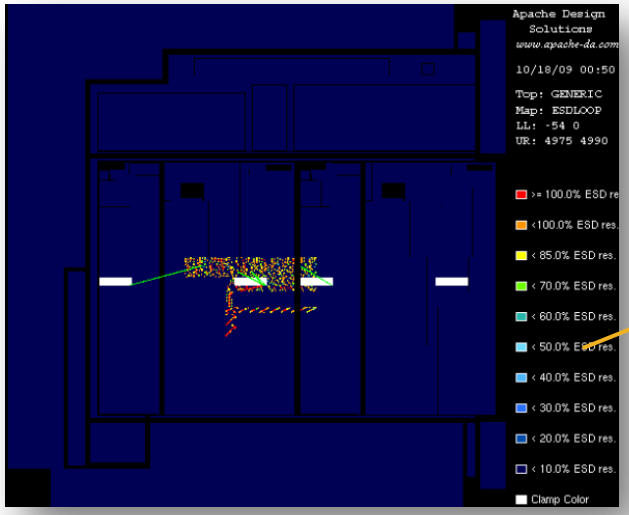
esd_summary.rpt
esd_pass.rpt
esd_fail.rpt
ClampInfo.rpt

PFS-CDM GUI Features

- Instance Pass/Fail and Loop/Arc R Color Maps
- Color maps will be gradient maps (by default) based on Pass/Fail threshold (similar to EM violation maps)
- The color is decided by % of violation. The higher the resistance compared to threshold, the brighter the color. The colors are configurable as in any other color map in RedHawk
- Commands: show esdloop and show esdarc

Instance highlighted in different colors

Clamps highlighted in White

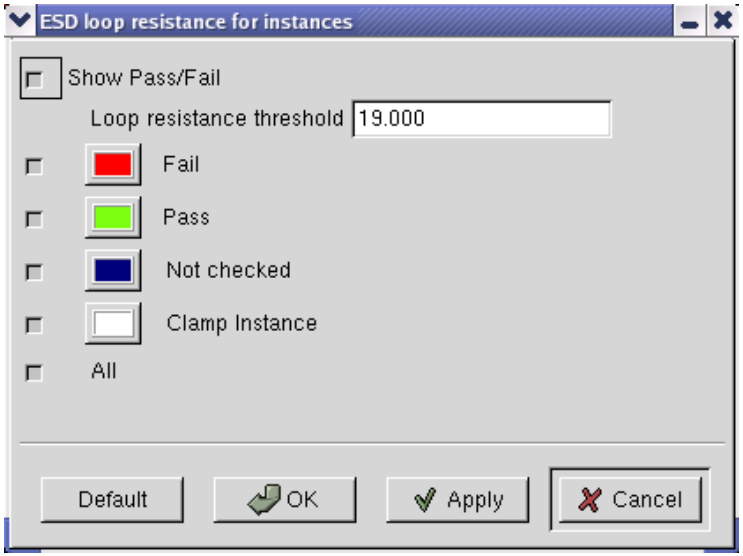


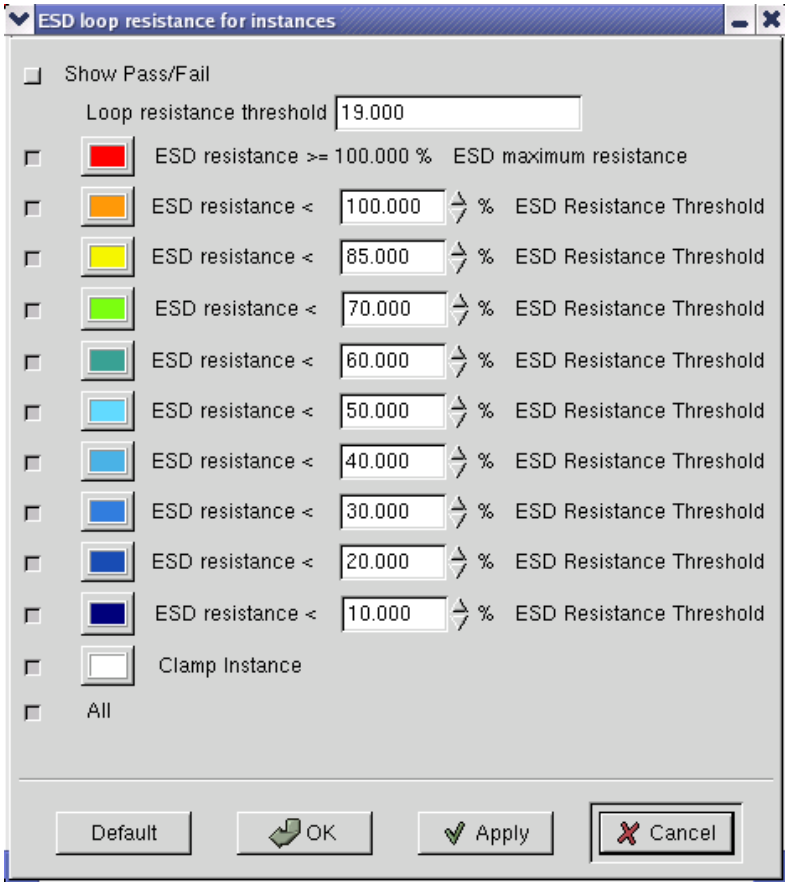
Resistance legend

Green – passing instances
Red – Failing instances

PFS-CDM GUI Features

- **Two ways to configure color maps through RedHawk's standard color map configuration window**
  - **Set threshold value to dynamically change pass/fail criteria**
  - **Show categorical map in terms of pass, fail, not run and clamp**



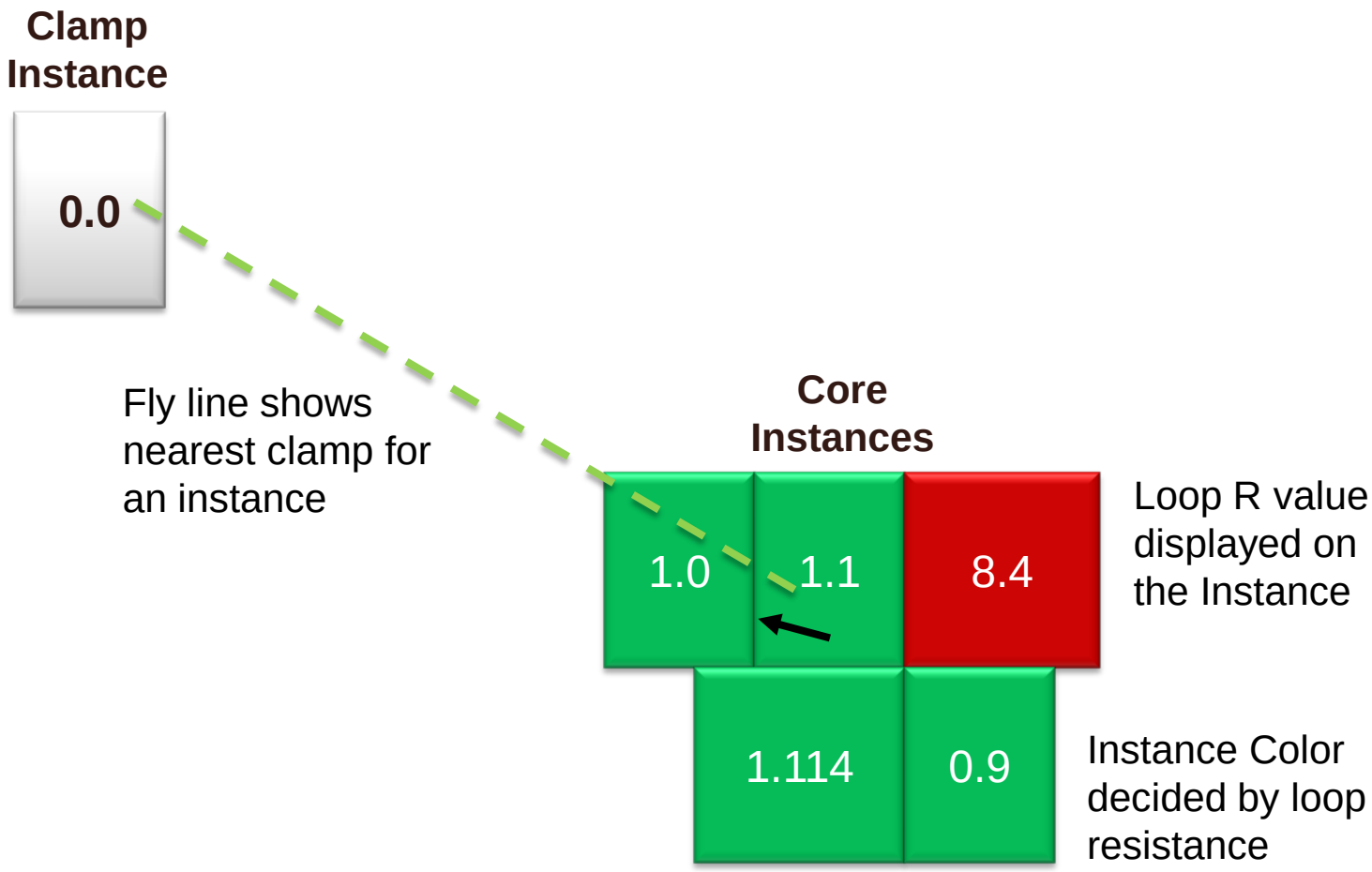


"show esdloop" color configuration ; Same for **"show esdarc"**

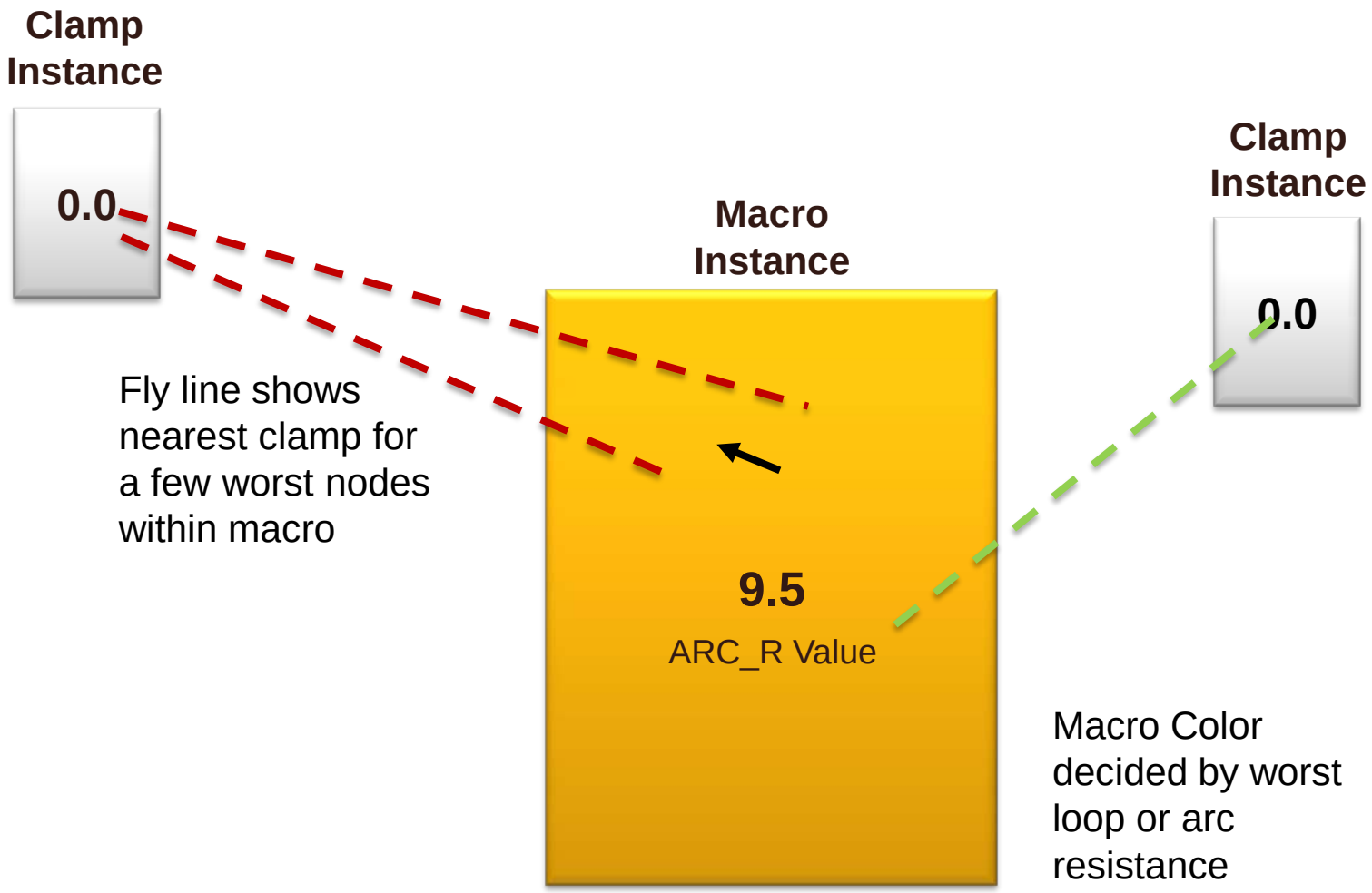
PFS-CDM GUI Features

- The clamp cell instances will be colored white to make them stand out
- When an instance is clicked, fly lines will show the nearest clamp instances (in terms of arc or loop resistances)
- Fly lines are red or green based on pass or fail
- Instances for which no results are available will have lowest fill color.
- The display is based on cumulative results from multiple runs
- When an instance is selected, its loop and arc resistance values to nearest clamps are printed in the tcl output window. Corresponding clamp instances are indicated with fly lines.

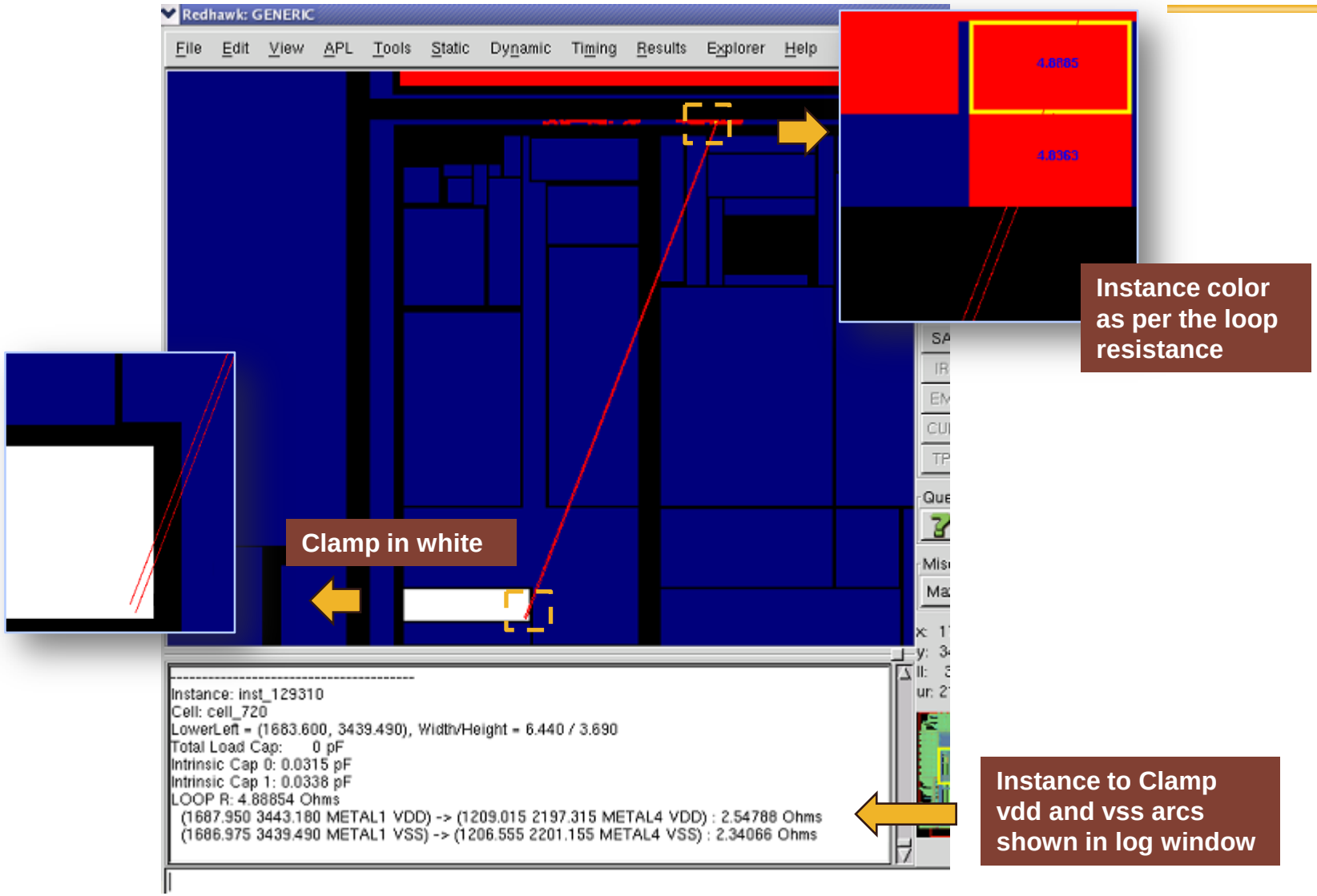
ESD Color Map for Core Instance



ESD Color Map for Macro



ESD Color Map Example – Generic Design



CDM Analysis – Hands-On Training Testcase

Download Testcase

- **Generic testcase**
  - **Download instructions**

```
% ftp ftp.apache-da.com
Name: anonymous
Password: <your email address>
ftp> cd outgoing
ftp> get GENERIC_tutorial.tar.gz
ftp> bye
```

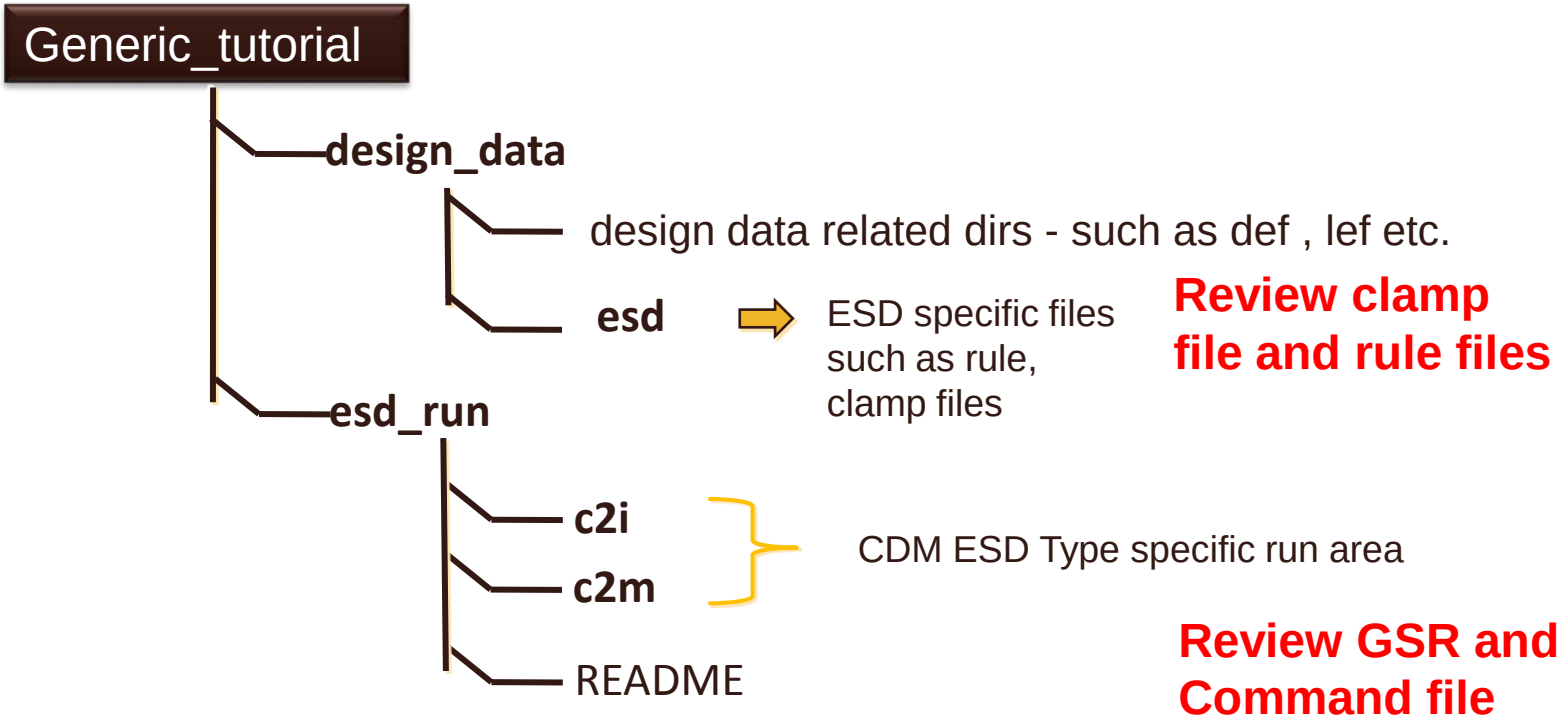
  - **Untar testcase**

```
% cd <work_area>
% gtar –zxvf GENERIC_tutorial.tar.gz
% \rm GENERIC_tutorial.tar.gz
% cd GENERIC_tutorial.tar.gz/
% more README
```

Approximately 0.5GB space is required for testcase

Directory Structure

- **Directory structure in <work_area>/Generic_tutorial/esd_run**



Run PathFinder Analysis

- **Clamp file is common to all analysis**
- **Rule file is specific to the ESD analysis**

```
BEGIN_CLAMP_CELL
NAME cell_10
  PIN VSS 10, 68 METAL4
  PIN VDD 10, 73 METAL4
  ESD_PIN_PAIR VDD VSS
  RON 0.0001
END_CLAMP_CELL
```

Clamp File

```
BEGIN_ESD_RULE
NAME        C2I_STANDARD_CELLS
TYPE        CLAMP2INST
INST_FILE   inst_std_cells.list
ARC_R       2.5
LOOP_R      5
END_ESD_RULE
```

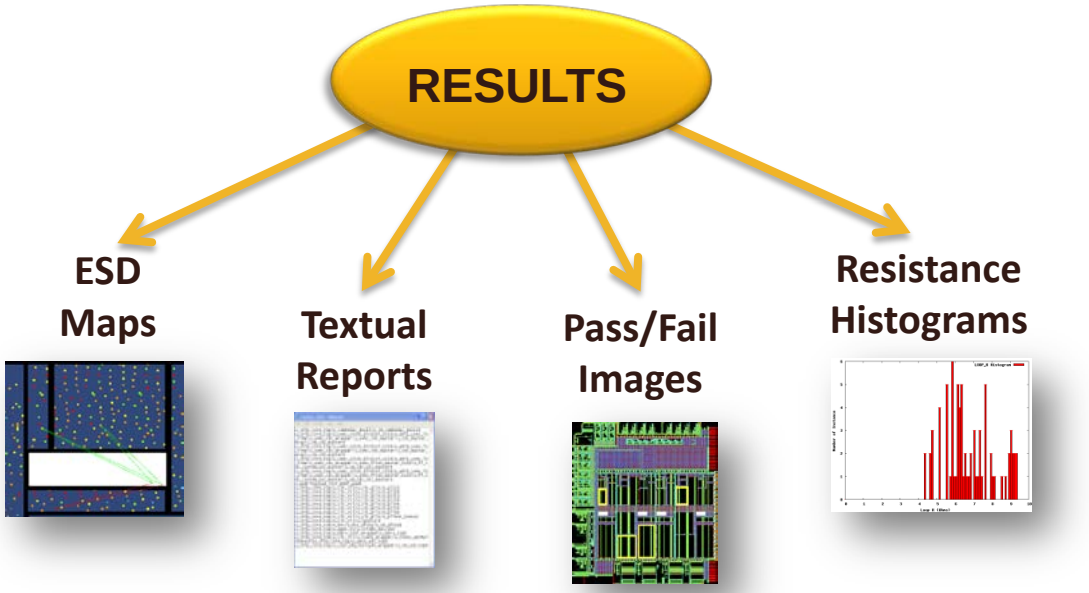
Rule file for C2I

- **Run ESD analysis**

```
> cd  c2i                    # go to esd analysis specific run area
> RedHawk –f run_c2i.tcl &   # run the analysis
```

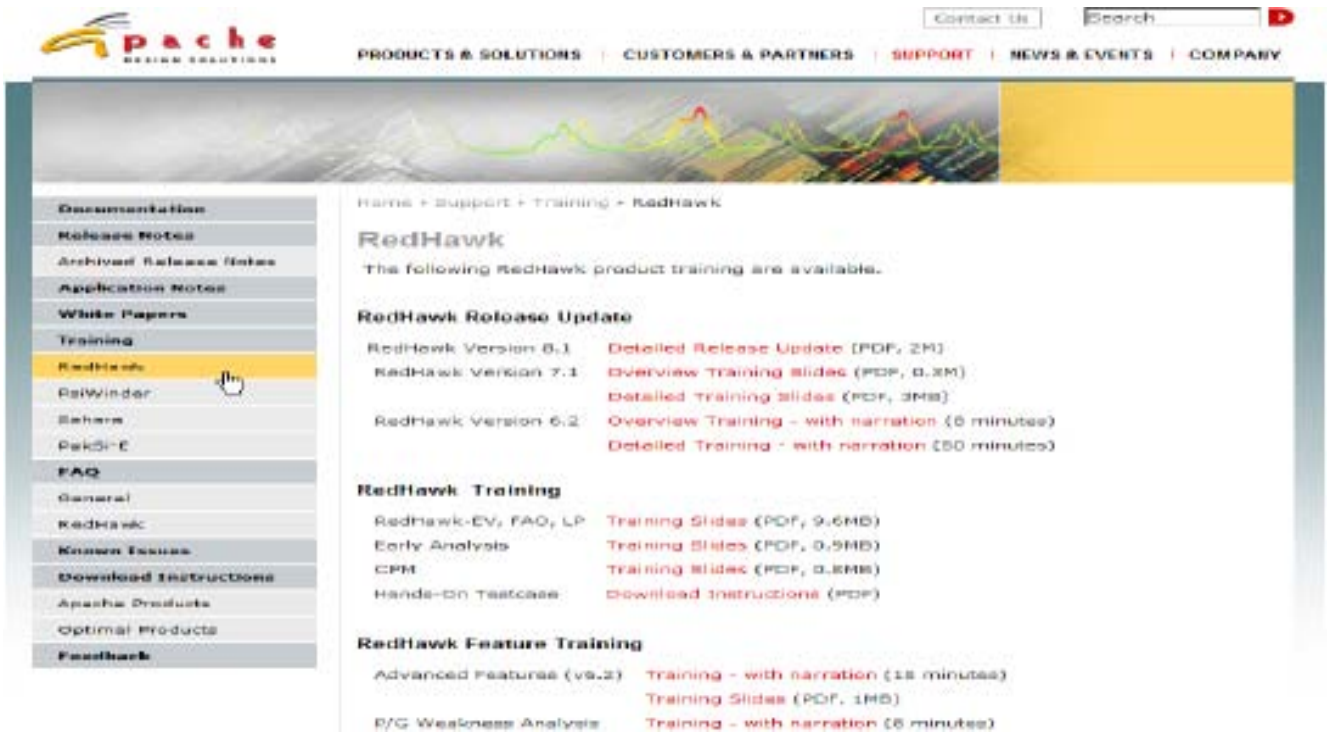
Result Analysis (CDM)

- Check CDM results in adsRpt/ESD/ or the specified output directory at the esdcheck command line
- Verify Results



More Information

- **Manual, Release Notes and Application Notes on Support Website**



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