PrimePower Cell EM(ElectroMigration) Analysis on Advanced Process

MH.Tsai, Joe.Chueh
Global Unichip Corporation

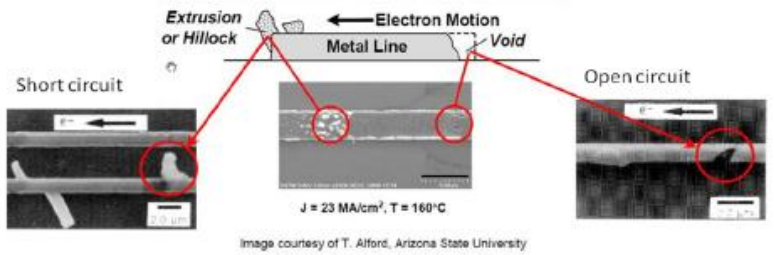
Agenda

- **Cell EM Introduction**
- **Cell EM Trend?**
  - Analyze by Cell EM Library: Cross Cell Type / Driving / Process
  - Analyze by Real Case: Different Process / Design Spec
- **Experiment Result**
- **N7/N6/N5/N3 Cases Sharing**
- **Summary**

Agenda

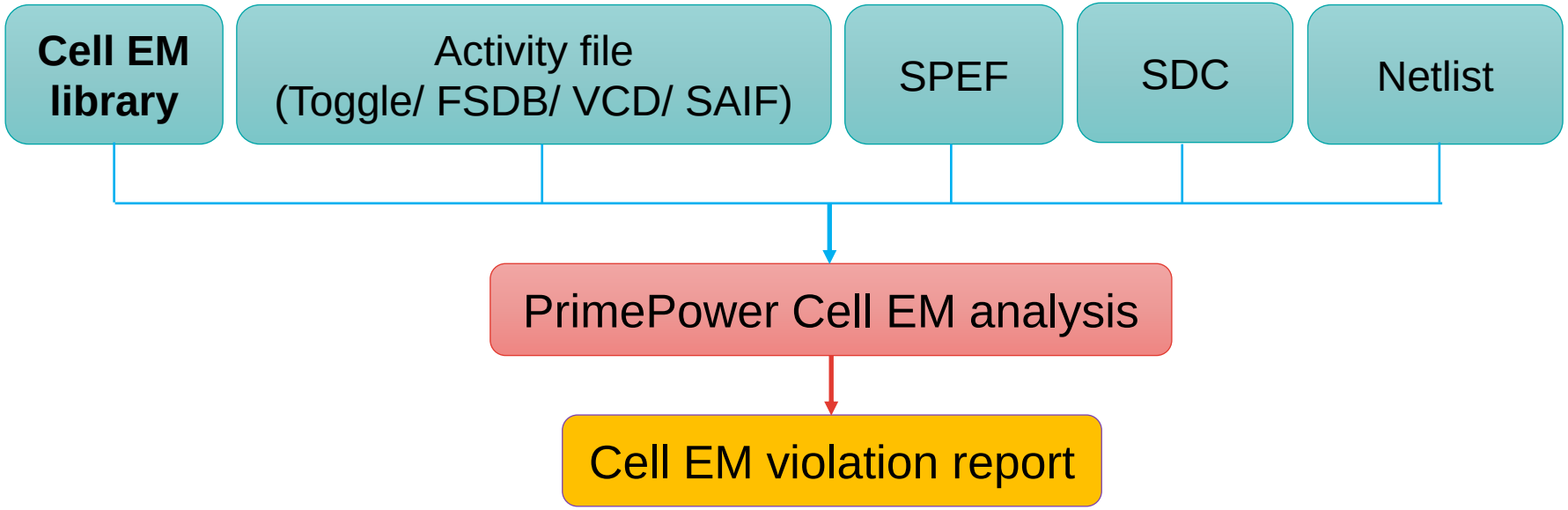
- **Cell EM Introduction**
- **Cell EM Trend?**
  - Analyze by Cell EM Library: Cross Cell Type / Driving / Process
  - Analyze by Real Case: Different Process / Design Spec
- **Experiment Result**
- **N7/N6/N5/N3 Cases Sharing**
- **Summary**

Introduction



- EM(ElectroMigration)
  - Current density through the conductor is high enough to cause the drift of metal ions.

- PrimePower Cell EM analysis flow



Introduction – Cell EM library

- Cell EM library includes three current type table
  - Average / RMS / Peak current table (represent by toggle rate)

- EM library example:

Maximum toggle rates indexed by input transition time and output capacitance

```
em_lut_template(em_template_3x3) {
   variable_1 : input_transition_time;
   index_1("0, 1, 2");
   variable_2 : total_output_net_capacitance;
   index_2("0, 1, 2"); }
electromigration () {
      related_pin : "i0";
      current_type: average | rms | peak ;
      em_max_toggle_rate (em_template_3x3)
{
       index_1 ("0.002, 0.004, 0.008");
       index_2 ("0.0001, 0.0536, 0.0132");
       values ( \
        "2093.356, 390.168, 156.066," \
        "2093.356, 390.168, 156.066,", \
        "2093.356, 390.168, 156.066," \
         );      }
```

Electromigration tables can be provided for different current types which correspond to different EM issues

Current Type	EM Issue
Average	Self healing in AC
RMS	Joule Heating
Peak	Reliability

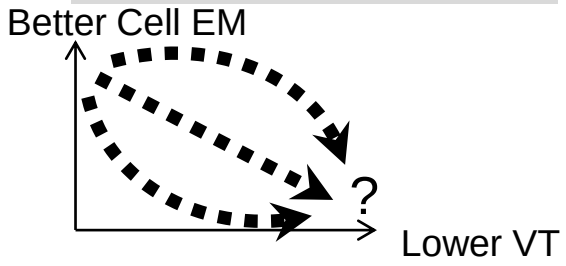
Agenda

- Cell EM Introduction
- **Cell EM Trend?**
  - Analyze by Cell EM Library: Cross Cell Type / Driving / Process
  - Analyze by Real Case: Different Process / Design Spec
- Experiment Result
- N7/N6/N5/N3 Cases Sharing
- Summary

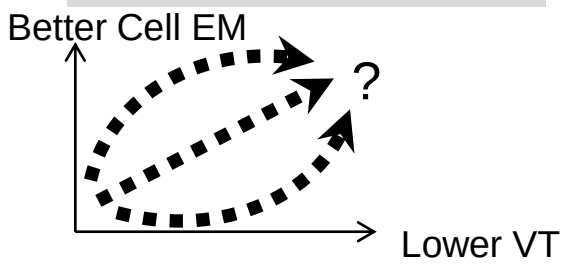
Cell EM Trend? – Analyze by Cell EM Library

- What's cell type & driving have worse EM ?

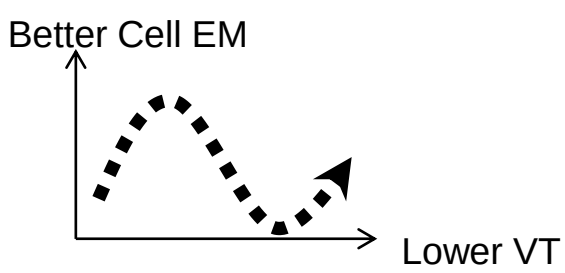
Lower VT leads worse EM?
Curve or linear relation?



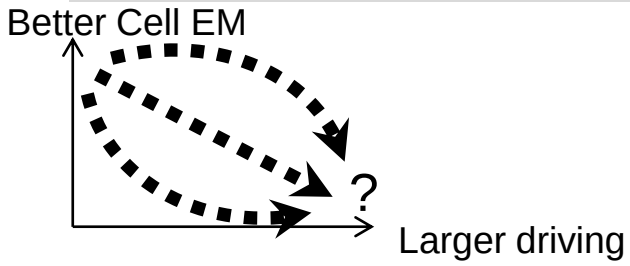
Lower VT leads better EM?
Curve or linear relation?



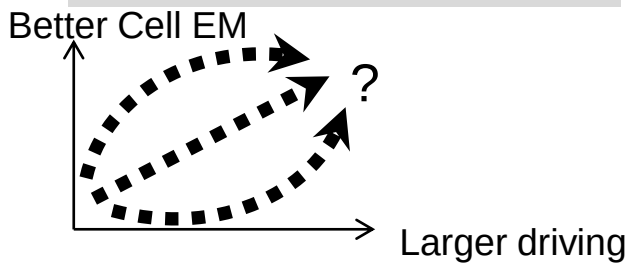
No relation?



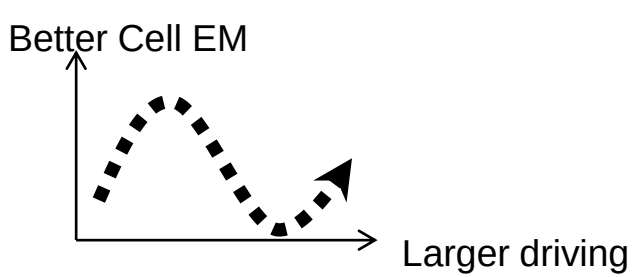
Larger driving leads worse EM?
Curve or linear relation?



Larger driving leads better EM?
Curve or linear relation?

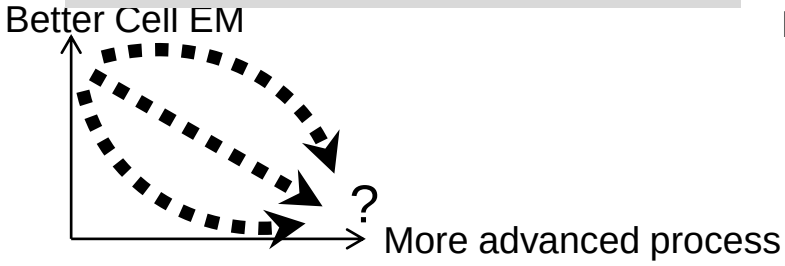


No relation?

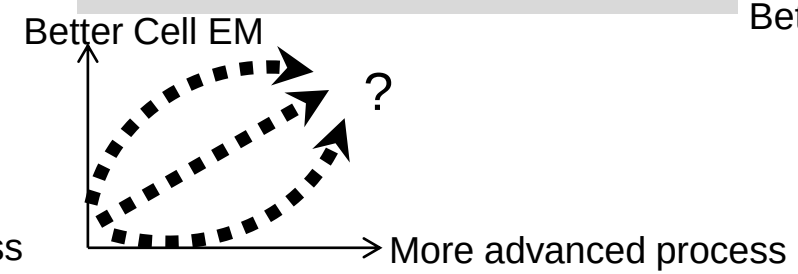


- Whether more advanced process with worse EM ?

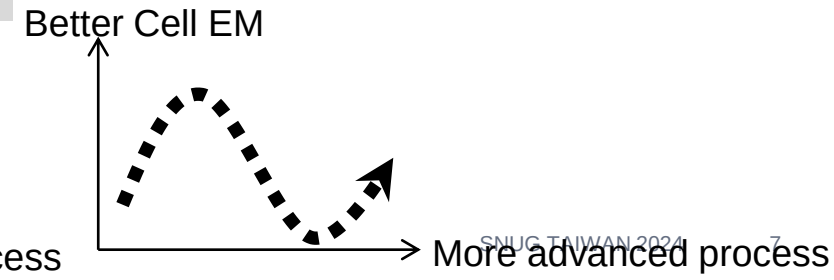
More advanced process leads worse EM?
Curve or linear relation?



More advanced process leads better EM?
Curve or linear relation?



No relation?



Cell EM Trend? – Analyze by Real Case

- **When should we run the PrimePower Cell EM analysis?**
  - Run for every version of Post-APR netlist?
  - Run after fixing max_cap / max_tran ?
- **What's the scale number of Cell EM violations?**
  - Dozens? Hundreds? Thousands? Tens of thousands?
- **When should we fix the PrimePower Cell EM violations?**
  - The first version of Post-APR netlist?
  - The first version of max_tran/cap fixing completed?

Agenda

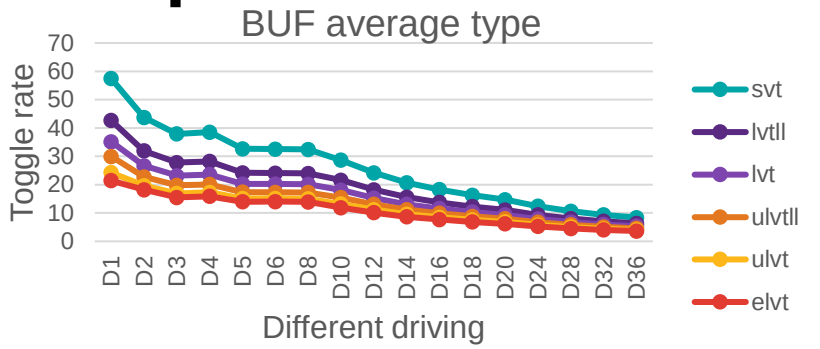
- Cell EM Introduction
- Cell EM Trend?
  - Analyze by Cell EM Library: Cross Cell Type / Driving / Process
  - Analyze by Real Case: Different Process / Design Spec
- **Experiment Result**
- N7/N6/N5/N3 Cases Sharing
- Summary

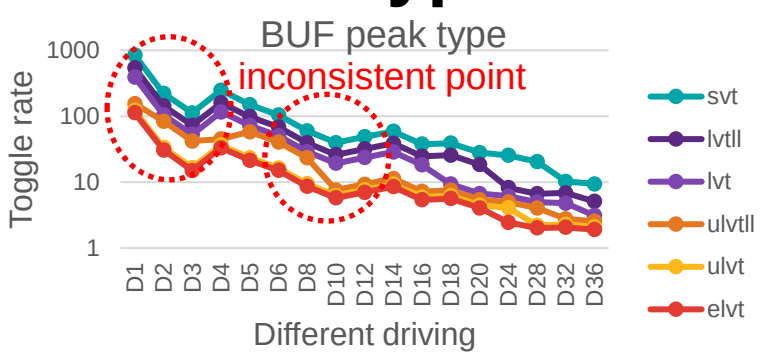
Experiment result – Background & Conclusion

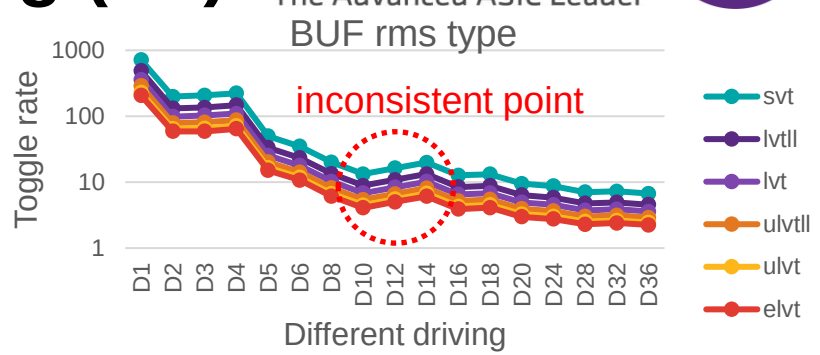
- **Experiment background**
  - Toggle rate value is based on the "5*5” in the table
  - Checking 4 cell types (BUF, AOI, SDF , MB4)
  - Process including N5/N3

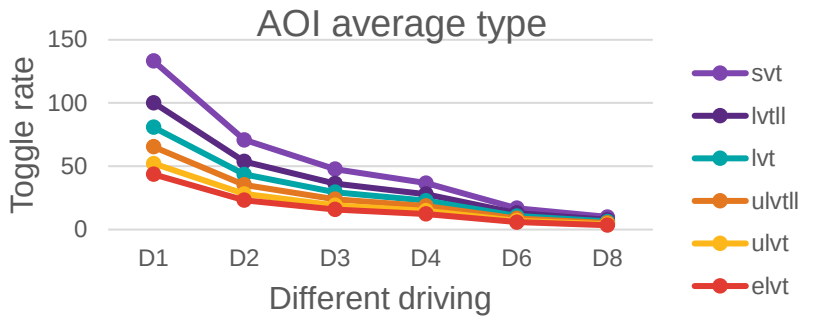
- **Experiment conclusion**
  - The lower VT leads worse EM (smaller toggle rate)
  - The larger driving cell leads worse EM (smaller toggle rate)
    - Except few cells(peak/rms index), most cells are in the consistent trend
  - More advanced process doesn’t lead worse EM: no consistent relation.

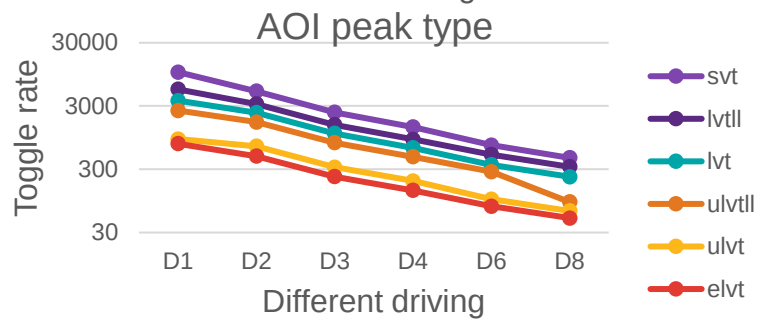
Experiment result – Cross Cell Type & Driving (N5)

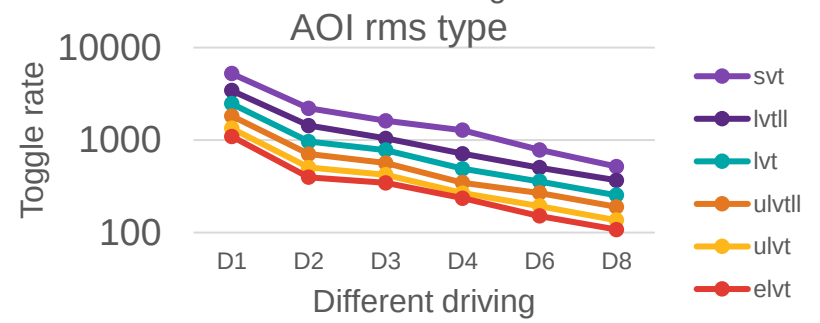


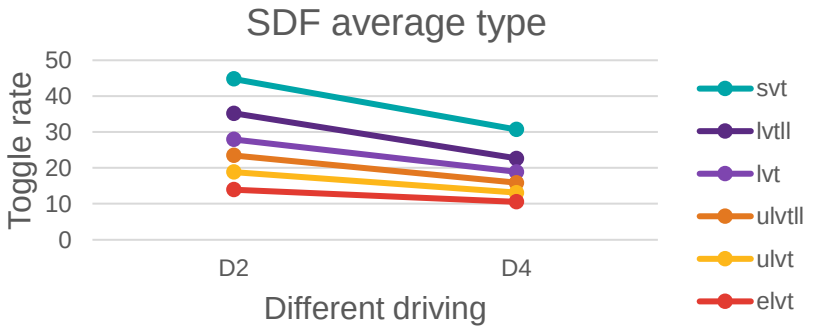


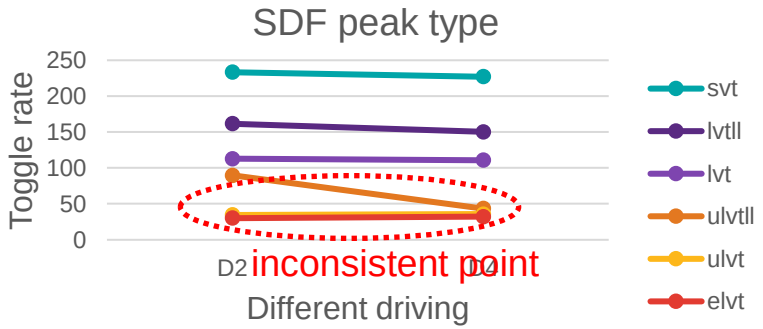


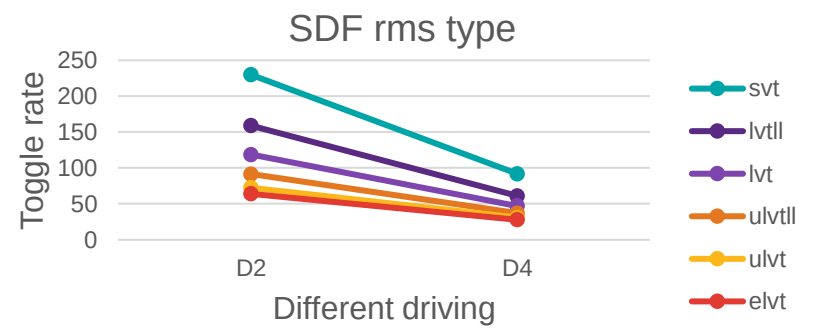


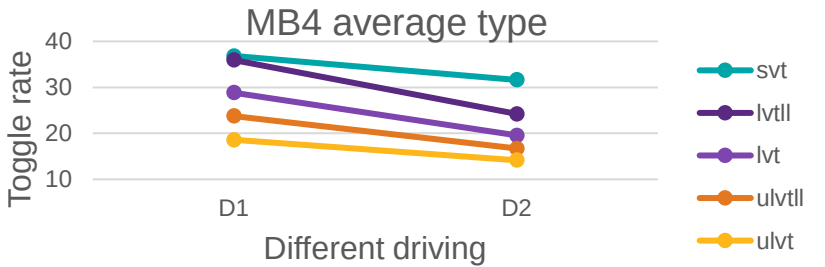


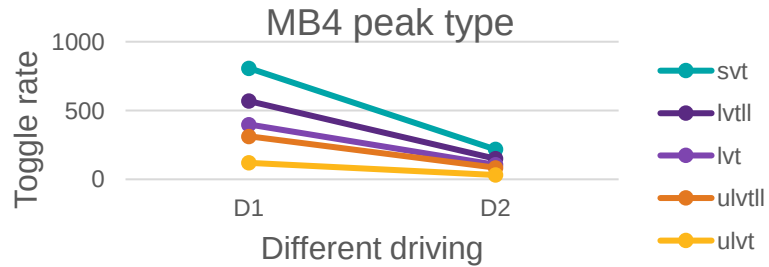


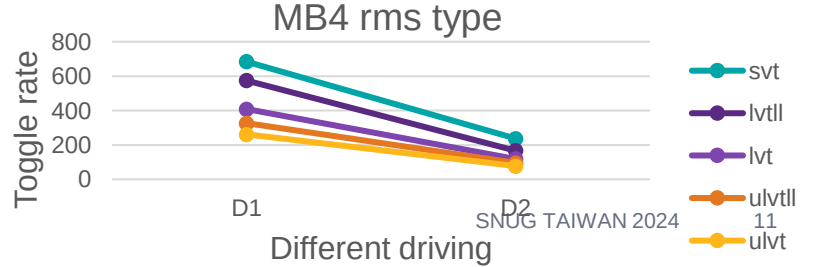




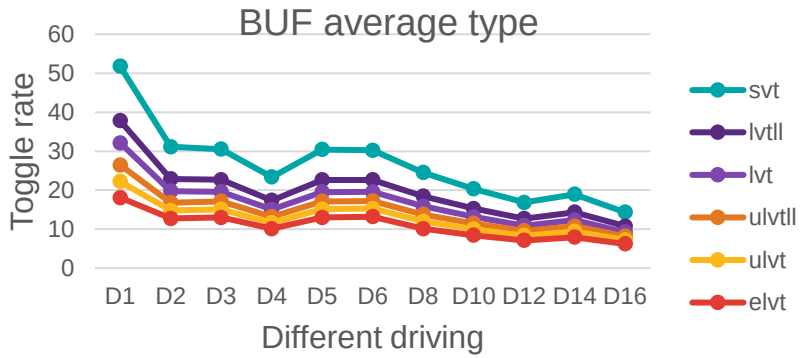


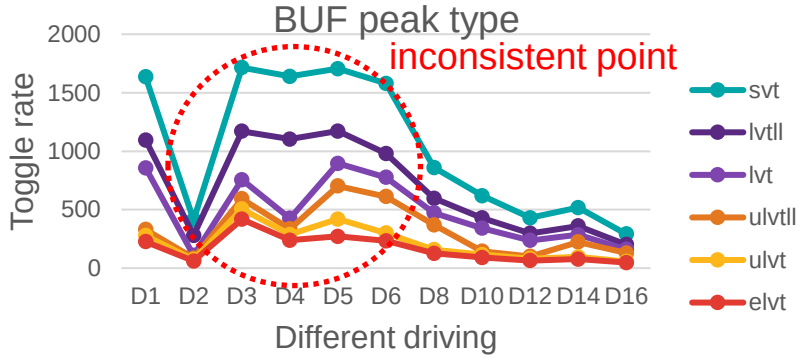


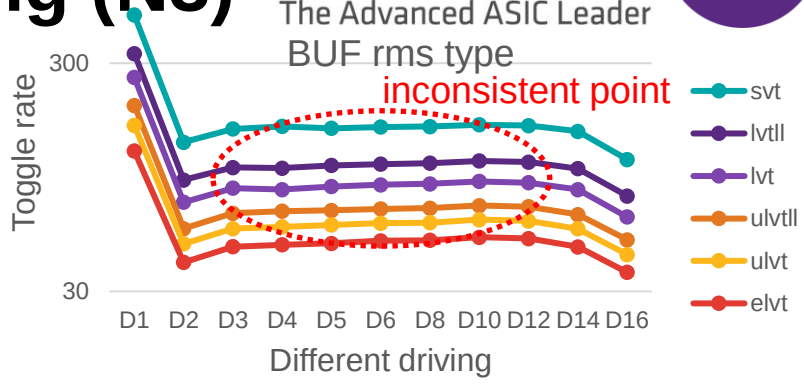


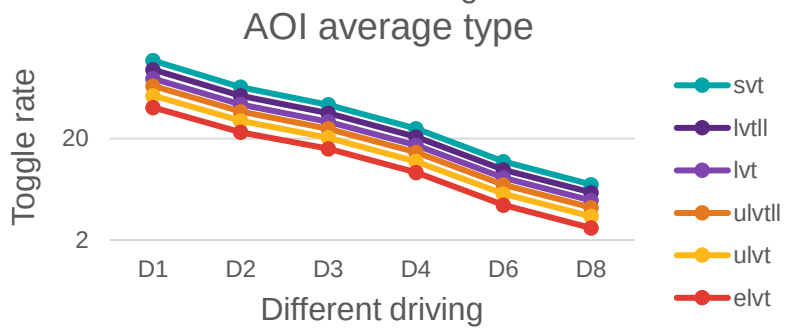


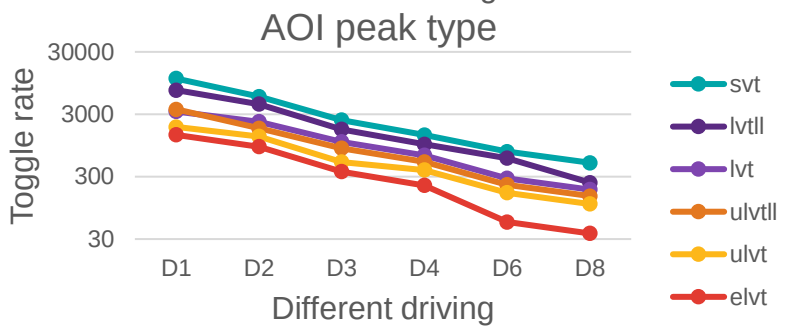
Experiment result – Cross Cell Type & Driving (N3)

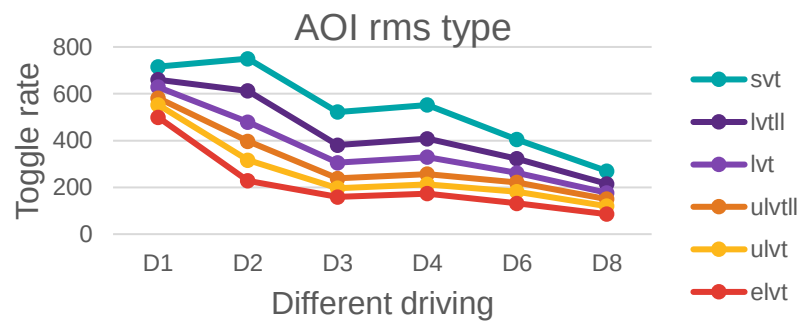


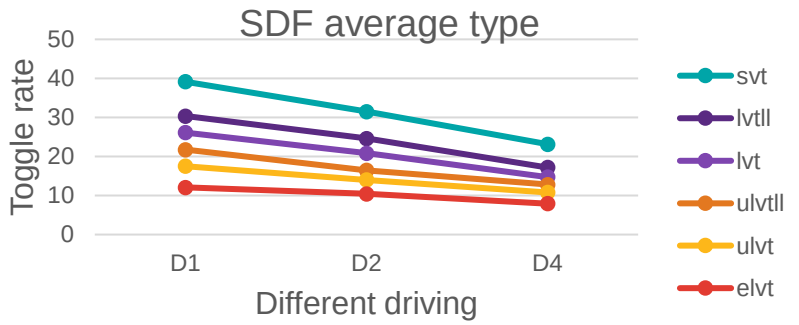


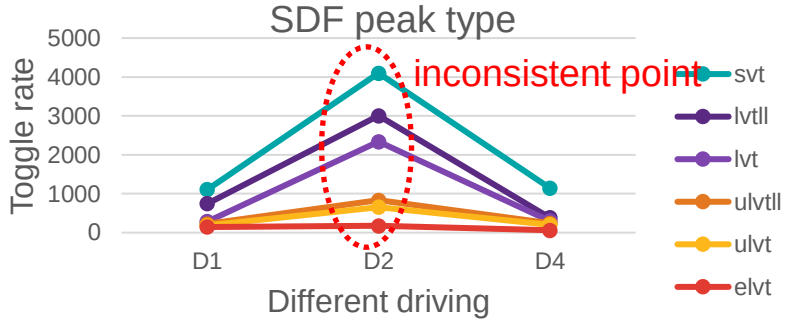


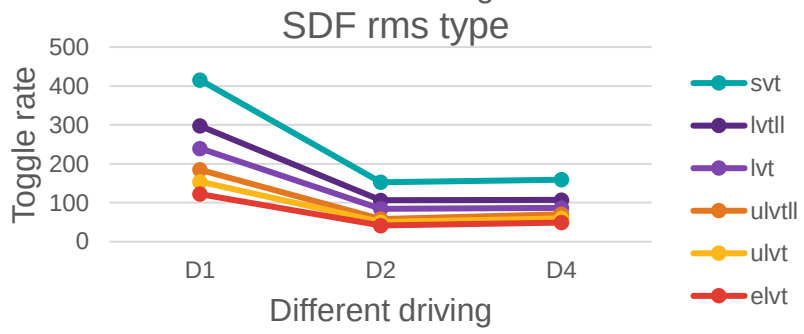


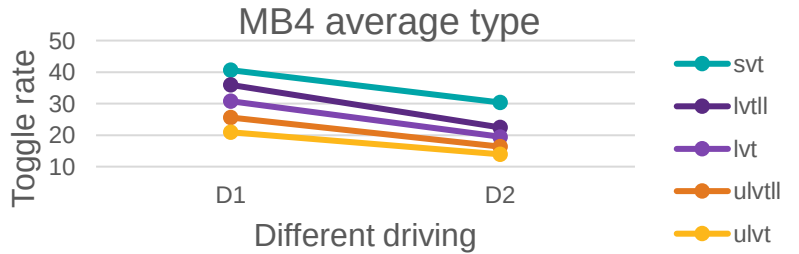


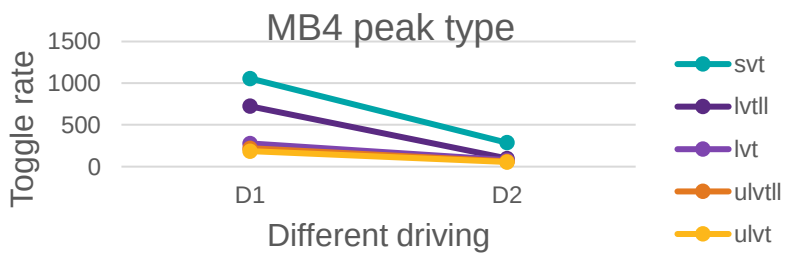


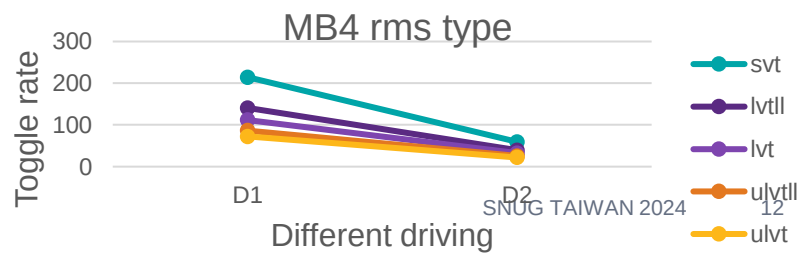




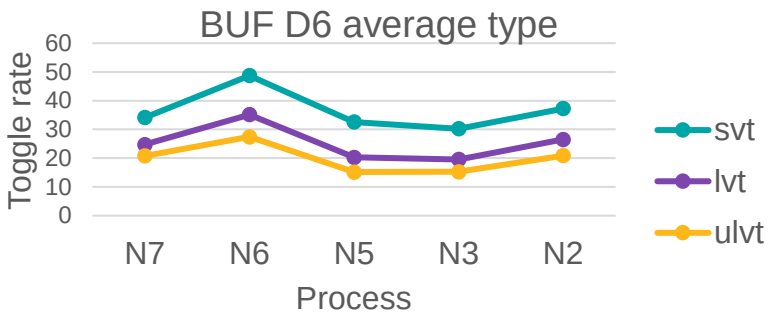


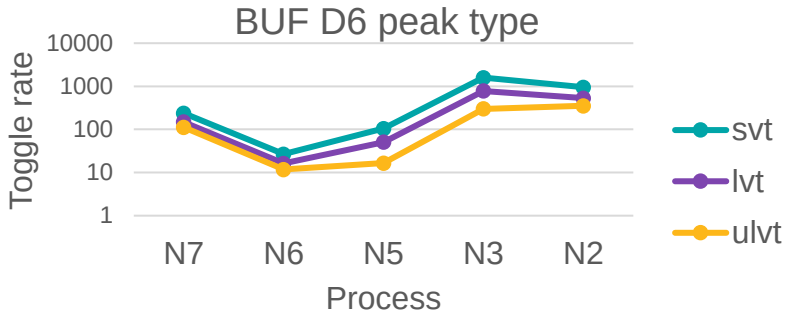


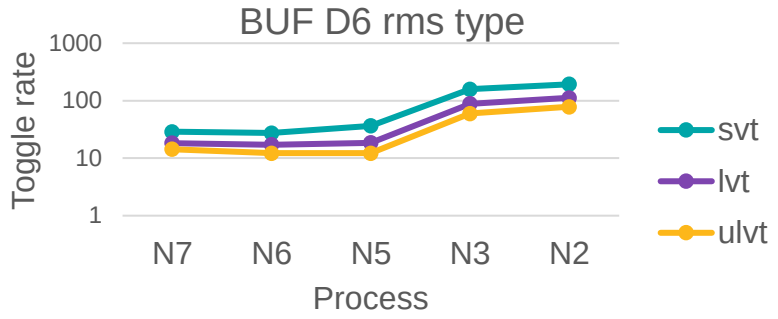


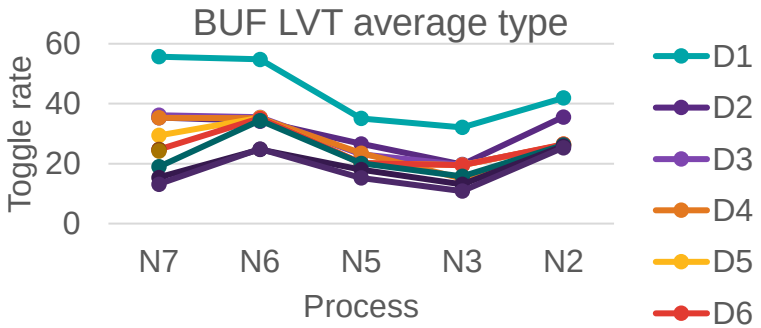


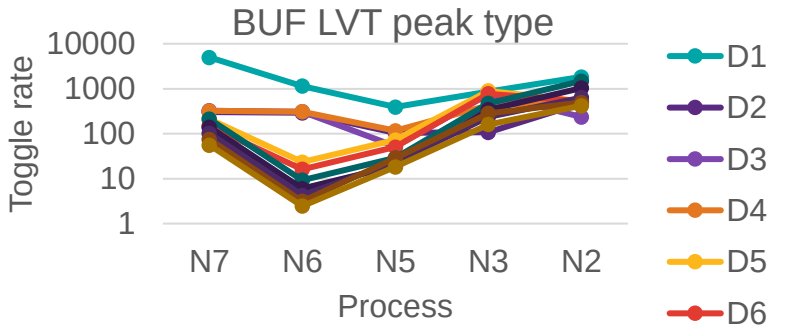
Experiment result – Cross Process

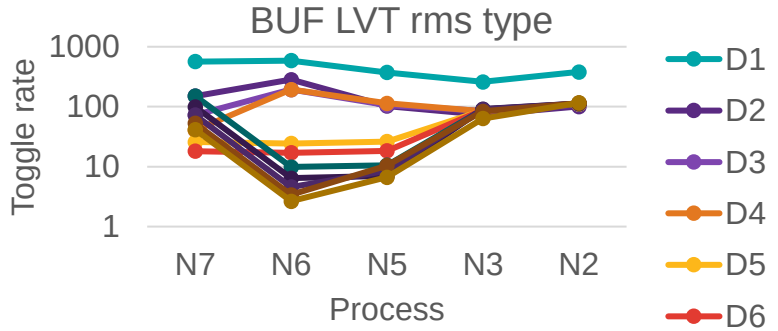


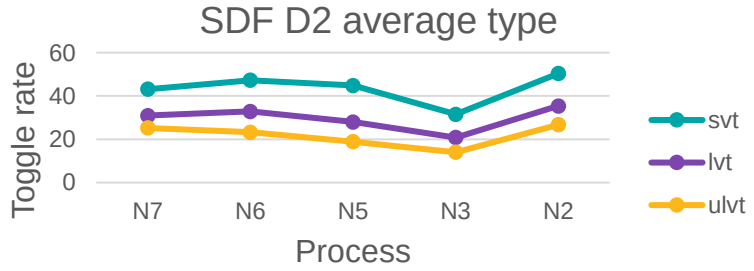


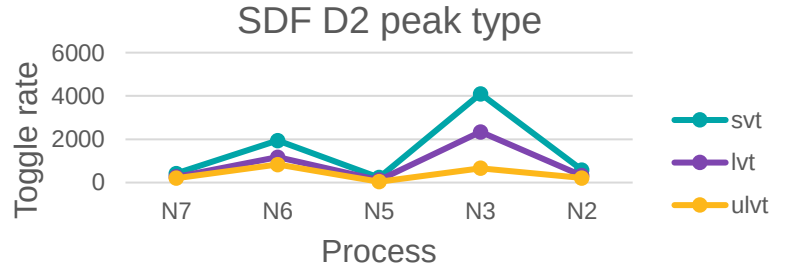


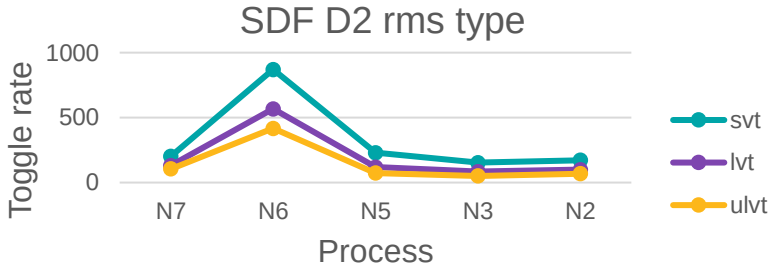


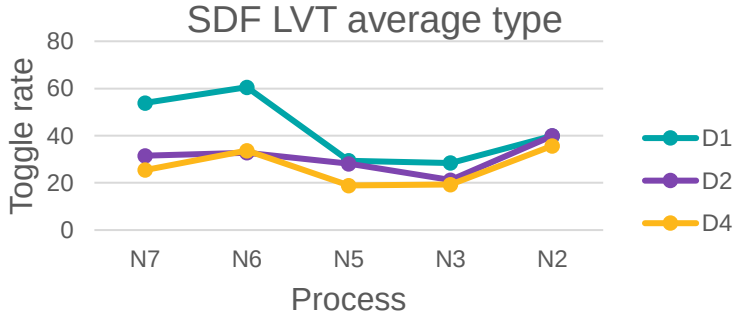


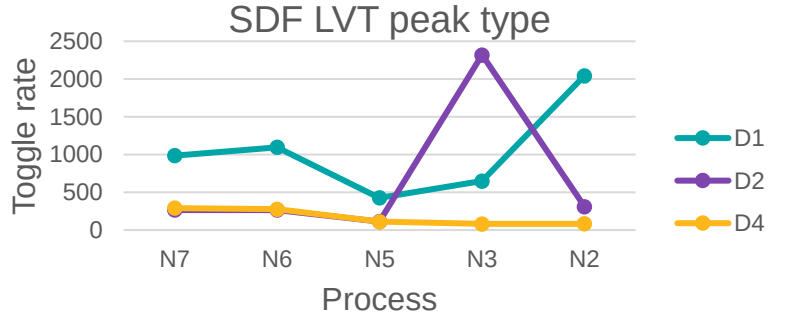


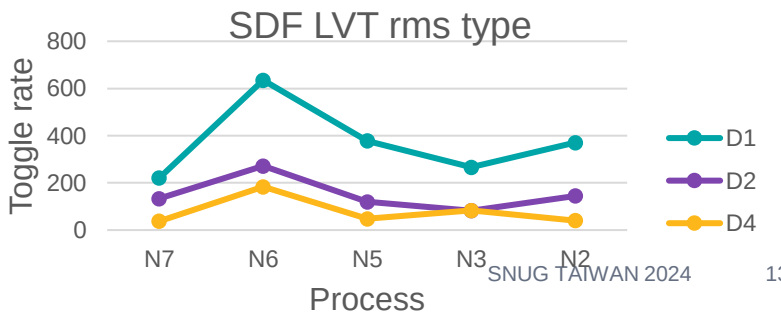












Agenda

- Cell EM Introduction
- Cell EM Trend?
  - Analyze by Cell EM Library: Cross Cell Type / Driving / Process
  - Analyze by Real Case: Different Process / Design Spec
- Experiment Result
- **N7/N6/N5/N3 Cases Sharing**
- Summary

Advanced Process Case Sharing

- Suggest to do cell EM analysis after the max_tran/cap fixing
  - Following case results are based on the max_tran/cap fixing completed
- All of the cases don't have cell EM violation even 2GHz speed

Process	Design Info	EM violation number	Run time	Mem usage
N3	Instance count : 2K Clock speed : 2GHz	0	20 secs	2GB
N5	Instance count : 43M Clock speed : 2GHz	0	5.23 hours	84GB
N5	Instance count : 250M Clock speed : 2GHz	0	32.2 hours	520GB
N6	Instance count : 6M Clock speed : 2GHz	0	2.35 hours	45GB
N7	Instance count : 8M Clock speed : 0.5GHz	0	1 hour	20GB

Agenda

- Cell EM Introduction
- Cell EM Trend?
  - Analyze by Cell EM Library: Cross Cell Type / Driving / Process
  - Analyze by Real Case: Different Process / Design Spec
- Experiment Result
- N7/N6/N5/N3 Cases Sharing
- **Summary**

Summary

- **PrimePower can analyze the Cell EM violations by library & design spec**
  - Library is the cell EM library. Design spec includes constraint, activity file etc.

- **Experiment to understand the cell EM trend**
  - Analysis by 4 cell type (BUF, AOI, SDF, MB4) @ process N5/N3
  - The lower VT leads worse EM (smaller toggle rate)
  - The larger driving cell leads worse EM (smaller toggle rate)
  - More advanced process doesn’t lead worse EM, it’s no consistent relation.

- **N7/N6/N5/N3 Cases Sharing**
  - Suggest to do cell EM analysis after the max_tran/cap fixing
  - All of the cases don’t have cell EM violation even 2GHz speed

THANK YOU
Our Technology, Your Innovation™