Case Study of Diagnosing Compound Hold-time Violations

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Problem Statement

- Nanometer process defects may cause silicon to fail scan test
- Design timing model variation may cause silicon to fail scan test
- Hold time violation has more possibility to occur in scan chain shift operation than in logic operation
- Advanced Scan chain diagnosis solution is useful to identify root cause of timing failures
Compound Hold-Time Error

Combinational Logic

Scan chain hold time error + System logic hold time error = Compound hold time error
Case Study

- 110nm process technology
- 0 yield for wafer sort
- One chain always fail
- Static Timing Analysis (STA) passed

Run diagnosis to locate the hold-time scan cell
Diagnosis

- Collect 50 failed scan patterns from ATE
- Run Yieldassist™ on the first 30 patterns

```c
// command: diagnose failures ./rpt/pat_all.cycle
... converting 31105 cycles to patterns.

#faulty_chains=1  #symptoms=1  #suspects=2  CPU_time=8.65sec
faulty_chain=1    #symptoms=1
symptom=1  #suspects=2
suspect  score  type         cell_number
----------  --------  ----------
 1     100  FAST_TO_RISE   1642
 2     100  FAST_TO_RISE   1643
```
Run Yieldassist™ on all 50 patterns

Diagnosis resolution dropped

Some failing bits in patterns [30-49] were caused by system logic hold-time error

Enhance Yieldassist™ to support compound hold-time diagnosis

Report hold-time errors are @ cells [1642, 1643]
Design ECO

- Bypass scan cells [1642, 1643]
- After ECO, yield > 90%
Timing Calculation

- Hold-time slack = 0.106ns
- Timing uncertainty = 0.130ns
- Total time margin = 0.106 + 0.130 = 0.236ns
- Assume clock skew has +/- 10% variation
- 2.931ns * 10% = 0.293ns > 0.236ns

Delay = 0.950 + 1.590 (WC)

Clock skew = 2.931 (WC)

Scan clock
Possible Root Cause

- Due to process variation, clock skew on silicon is larger than expected by STA

- Time margin is not enough for the given large clock skew

- Large clock skew brings more timing uncertainty and worse variation tolerance capability

- Timing or model variation of delay cell is larger other standard cell
Conclusions

- Unpredictable process or model variation may invalidate STA results
- Post-silicon diagnosis is useful to locate the weak hold-time scan cells
- Using diagnosis results to guide ECO, and use ECO to validate diagnosis results
- Root cause timing failures with diagnosis and STA