COEN 6521 VLSI Testing: SCOAP

Zeljko Zilic

McGill University
(in Ottawa)
zeljko@ece.mcgill.ca

Note

- Some material used in these slides based on Bushnell and Agrawal, “Essentials of Electronic Testing

Why and When to Simulate

- Simulations used on different levels of design process to check correctness of up-to-date product
  - Design verification/validation
    - Still most popular way of functional circuit verification at different levels of design refinement
    - Predominantly used in timing analysis
  - Testing
    - Major approach used in almost all testing techniques

SCOAP Contorallability and Observability

- Goldstein introducing controlability and observability measures to signal propagation through combinational and sequential block (SCOAP)
- SCOAP measurements on each line
  - Combinational 0-controlability, CC0(l)
  - Combinational 1-controlability, CC1(l)
  - Combinational observability, CO (l)
  - Sequential 0-controlability, SC0(l)
  - Sequential 1-controlability, SC1(l)
  - Sequential observability, SO(l)

SCOAP Measurements

- Combinational measures related to number of signals to be manipulated to control or observe l
- Sequential measures indicating number of clock cycles needed to control or observe signals on line l
- Controlability ranging from 1 to inf
- Observability ranging from 0 to inf
    - High measures indicating difficulties with controlling or observing given line

Combinational SCOAP Measures - Controlability

- Step 1: For all primary inputs set all CC0 = 1 and all CC1 = 1
- Step 2: Traverse in level order through circuit towards primary outputs updating controlability measures
  - Level of logic gate: max distance of its logic inputs from PIs

Combinational SCOAP Measures – Controlability, cont.

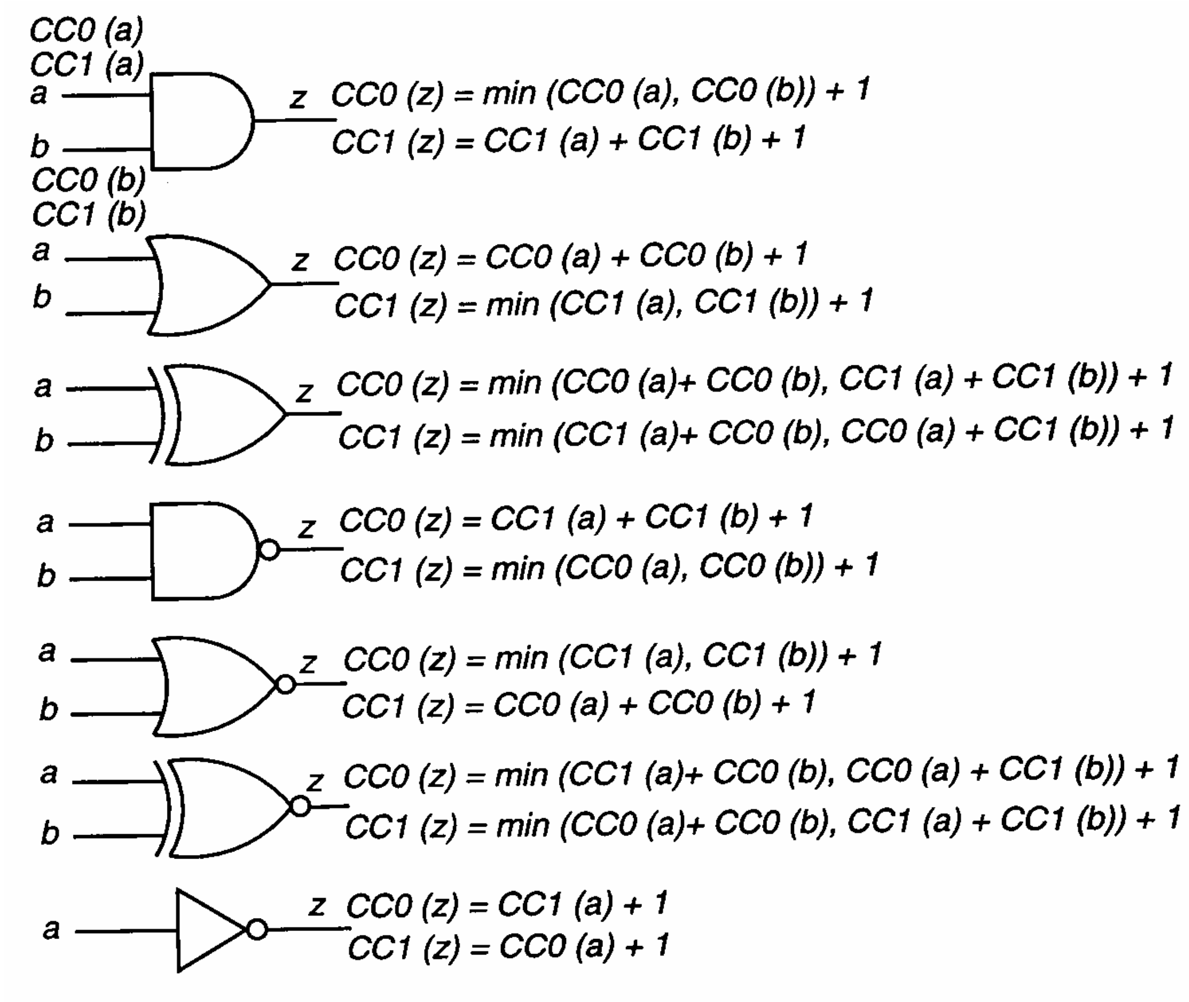
- Step 3: For each traversed logic gate add 1 to CC
  - If logic output produced by setting only one input to controlling value then

    output controllability = min(input controllability)+1
  - If logic output only obtained by setting all inputs to non-controlling values then

    output controllability = sum(input controllabilities)+1
  - If possible to control output by multiple input sets (XOR: "01" or "10" cause output 1) then

    output controllability = min(controllabilites of input sets)+1

Combinational SCOAP Measures – Controlability, cont.1



SCOAP Observability Measures

- Observability measures determined after controllability ones
  - For logic gates difficulty of observing input setup equaling observability of output + difficulty in setting all inputs to non-controlling values + 1 to accommodate for logic depth
  - No distinction between 0 and 1 observability: output observabilites of all primary outputs CO = 0

SCOAP Observability Measures, cont.

$CO(a) = CO(z) + CC1(b) + 1$
$CO(b) = CO(z) + CC1(a) + 1$

$CO(a) = CO(z) + CC0(b) + 1$
$CO(b) = CO(z) + CC0(a) + 1$

$CO(a) = CO(z) + \min(CC0(b), CC1(b)) + 1$
$CO(b) = CO(z) + \min(CC0(a), CC1(a)) + 1$

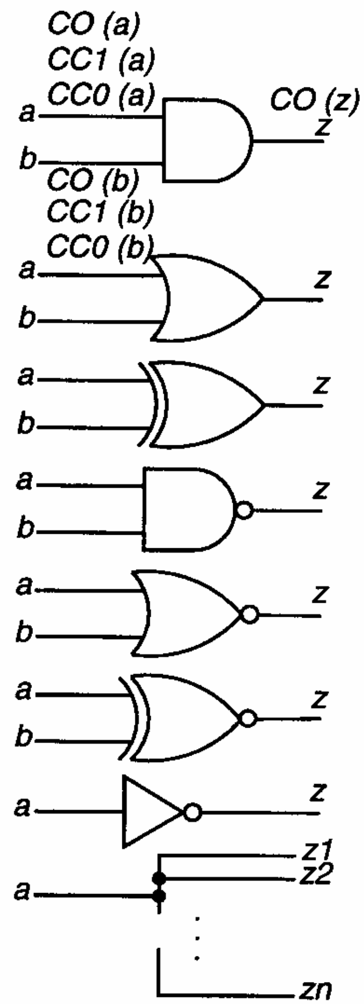
$CO(a) = CO(z) + CC1(b) + 1$
$CO(b) = CO(z) + CC1(a) + 1$

$CO(a) = CO(z) + CC0(b) + 1$
$CO(b) = CO(z) + CC0(a) + 1$

$CO(a) = CO(z) + \min(CC0(b), CC1(b)) + 1$
$CO(b) = CO(z) + \min(CC0(a), CC1(a)) + 1$

$CO(a) = CO(z) + 1$

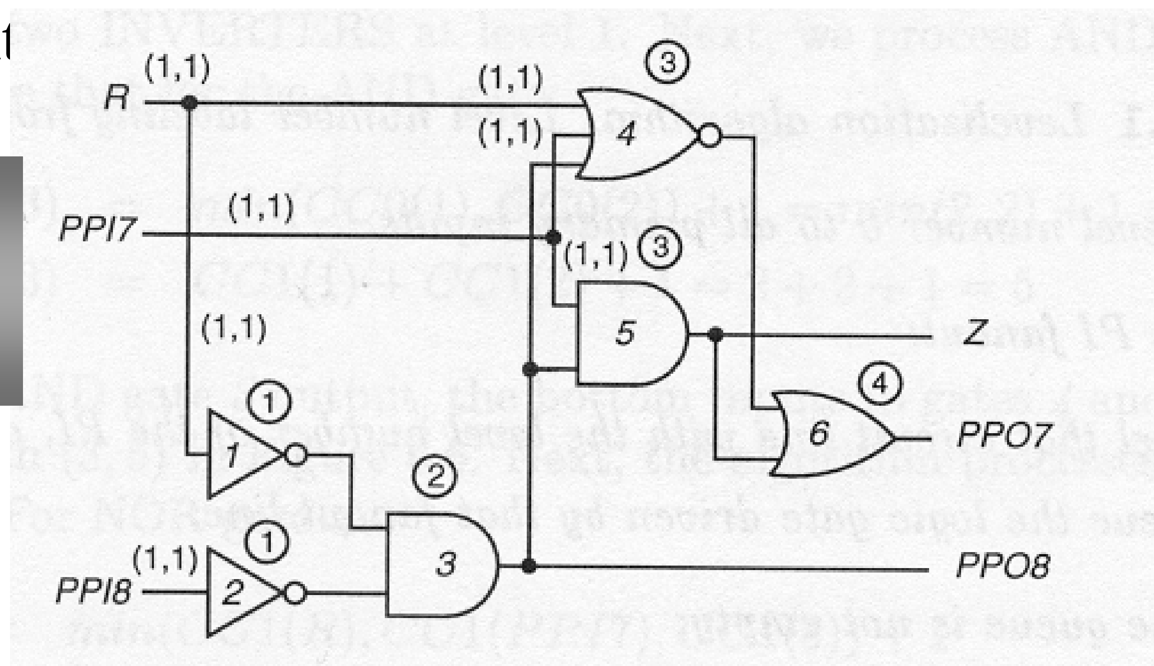
$CO(a) = \min(CO(z1), CO(z2), ..., CO(zn))$



Example: SCOAP

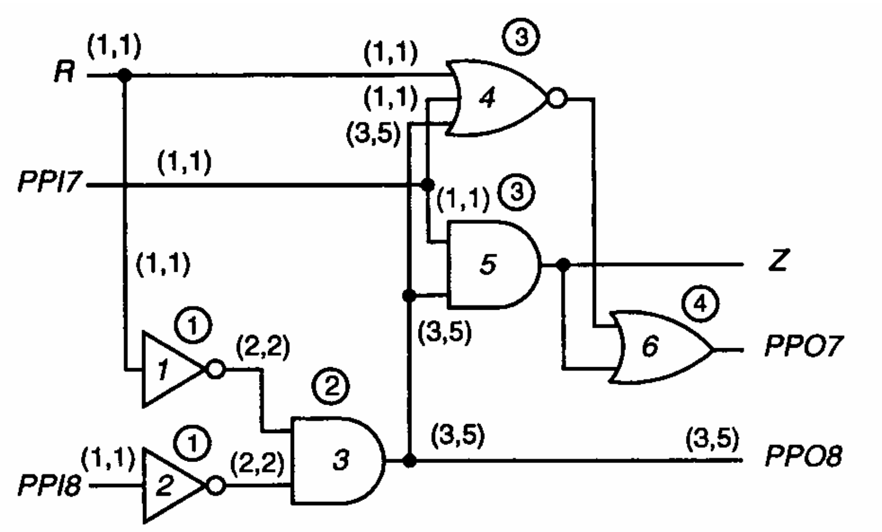
- Step 1: Label gates in level order
- Step 2: Label each fan-out as 1 (each fan-in is labeled as 0)
- Step 3: Label gate output with max level number of it + 1

Outputs of Inv1 and Inv1 Labeled with input level number + 1 = 1



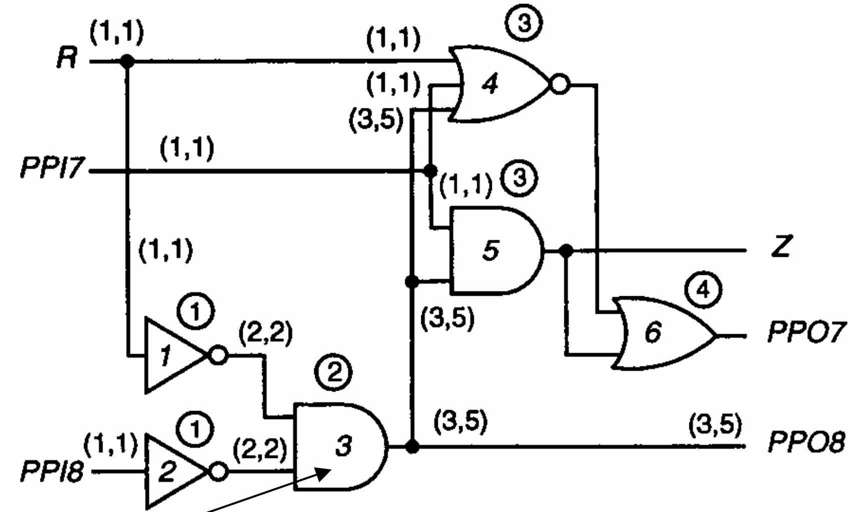
Example: SCOAP, cont.

- Assign (1,1) to all Pis: R PPI7, PPI8
  - Propagate labeling to all fanouts of above signals
- Labeling internal lines
  - Inverters: CC1(output) = CC0(input)+1 and v.v.
    - Outputs of inverters labeled (2,2)



Example: SCOAP, cont. 1

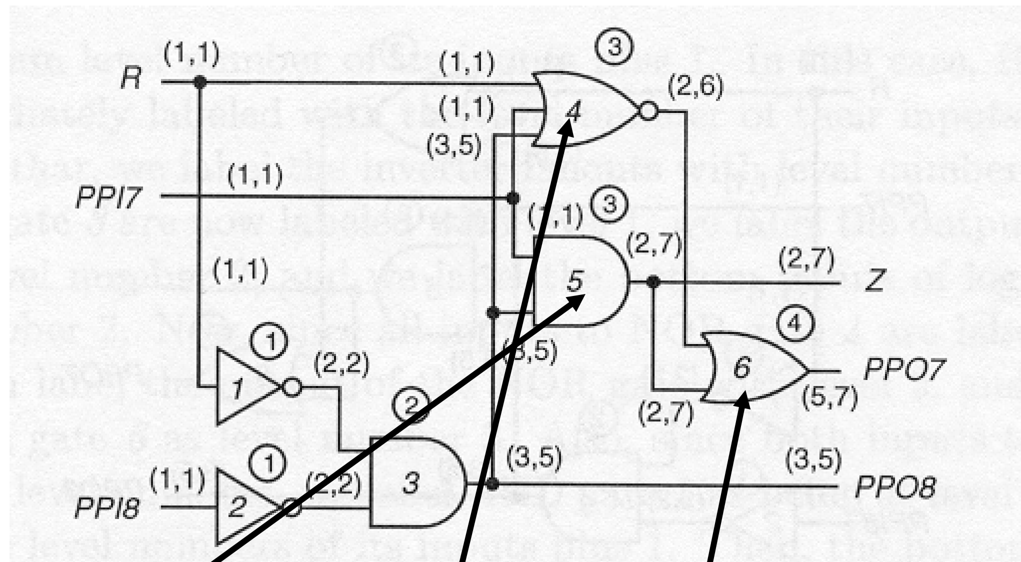
- Each logic gate processed in order imposed by level number



$$CC0(3) = min(CC0(1), CC0(2)) + 1 = min(2,2) + 1 = 3$$
$$CC1(3) = CC1(1) + CC1(2) + 1 = 2 + 2 + 1 = 5$$

$$CC0(4) = min(CC1(R), CC1(PPI7), CC1(3)) + 1$$
$$= min(1,1,5) + 1 = 2$$
$$CC1(4) = CC0(R) + CC0(PPI7) + CC0(3) + 1 = 1 + 1 + 3 + 1 = 6$$

Example: SCOAP, cont. 2



$$
\begin{aligned}
CC0(4) &= min(CC1(R), CC1(PPI7), CC1(3)) + 1 \\
&= min(1,1,5) + 1 = 2 \\
CC1(4) &= CC0(R) + CC0(PPI7) + CC0(3) + 1 = 1 + 1 + 3 + 1 = 6
\end{aligned}
$$

$$
\begin{aligned}
CC0(5) &= min(CC0(PPI7), CC0(3)) + 1 = min(1,3) + 1 = 2 \\
CC1(5) &= CC1(PPI7) + CC1(3) + 1 = 1 + 5 + 1 = 7
\end{aligned}
$$

$$
\begin{aligned}
CC0(6) &= CC0(4) + CC0(5) + 1 = 2 + 2 + 1 = 5 \\
CC1(6) &= min(CC1(4) + CC1(5)) + 1 = min(6,7) + 1 = 7
\end{aligned}
$$

Example: SCOAP, cont. 3

- Calculation of observability measures
  - From Pos backward
- Gates 3 and 5 cannot be assigned CO yet, gate 6 needs to be processed first