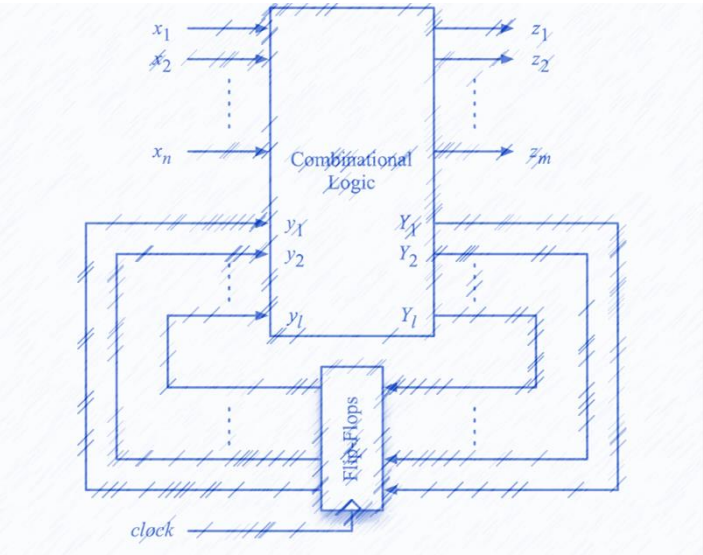
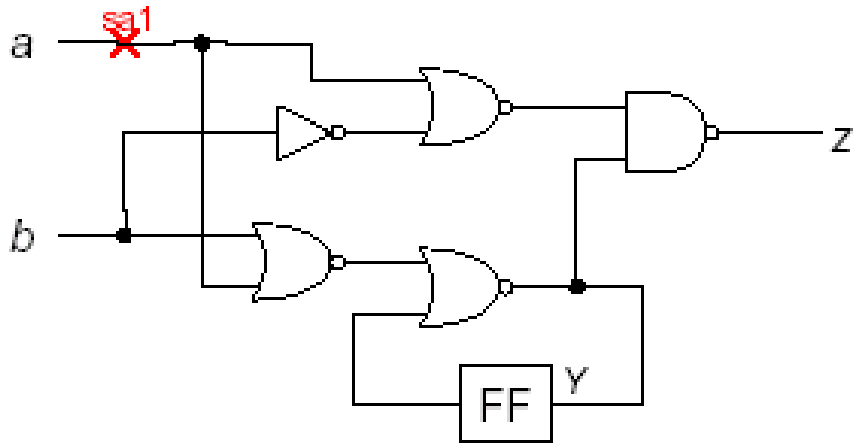
Sequential ATPG

- Introduction
- **Time-frame expansion methods**
  - The Extended D-algorithm [Kubo 68]
  - **9-valued D algorithm [Muth 76]**
  - EBT [Marlett 78], BACK [Cheng 88] *
  - Summary
- Simulation-based methods*
- Issues of Sequential ATPG*
- Conclusions



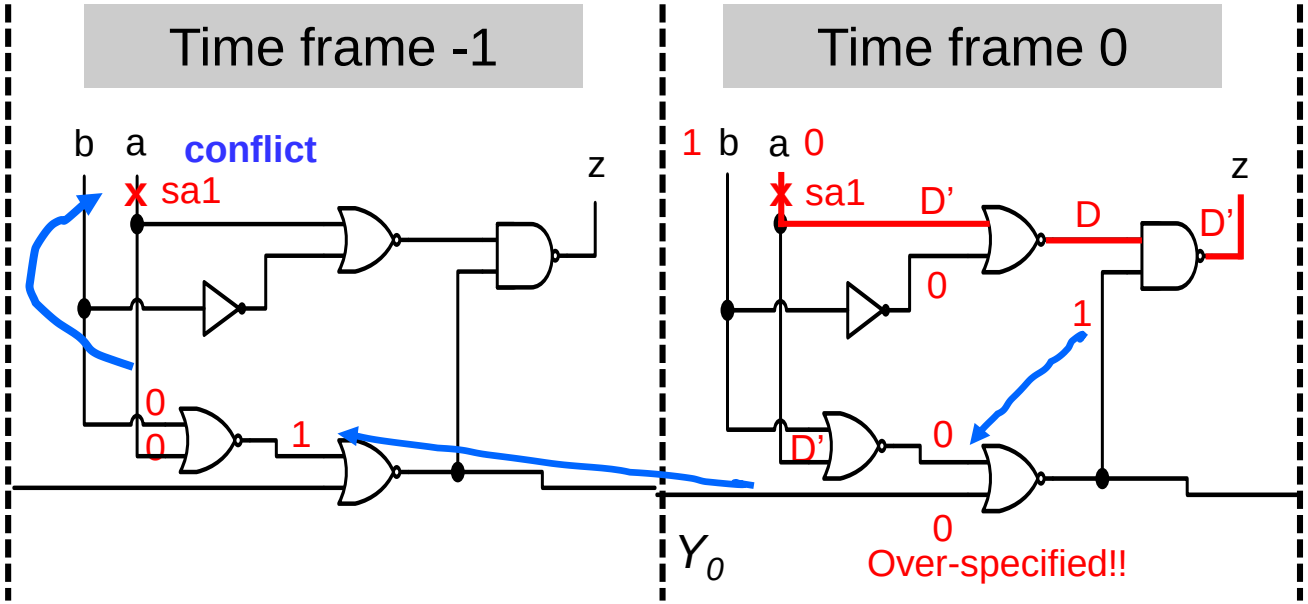
Quiz

Q: Given this test, can we detect the fault?
ANS:



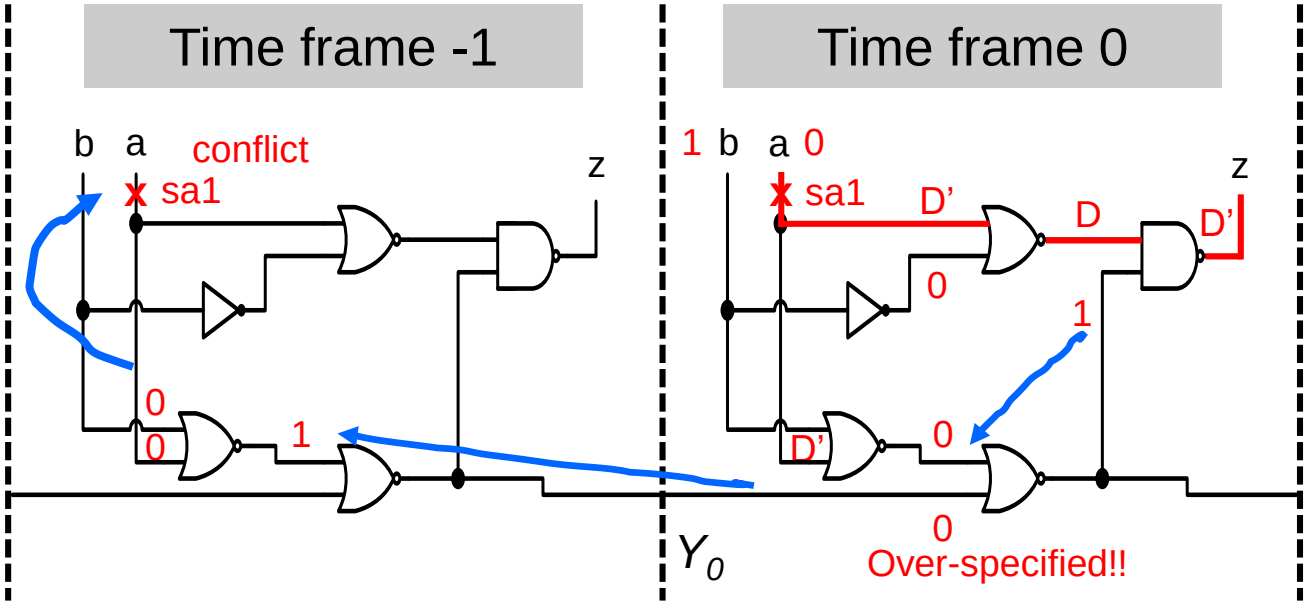
	a	*b*
v_1	0	0
v_2	0	1

Extended D-algorithm Fails!



- **Extended- D algorithm fails due to a conflict**
  - **Requires *a*=0 in time frame -1, but SA1**
  - **Actually, Y_0 is *over-specified* in 5-valued logic**

Why Fails?



- **Traditional 5-valued logic (0/0, 1/1, x/x, 0/1, 1/0) is NOT sufficient**
  - **cannot express 1/x, 0/x, x/0, x/1**

Q: How many total cases do we need?
ANS:

Nine-valued D-algorithm [Muth 76]

- **Solution: use *9-valued logic*, instead of 5-valued logic**

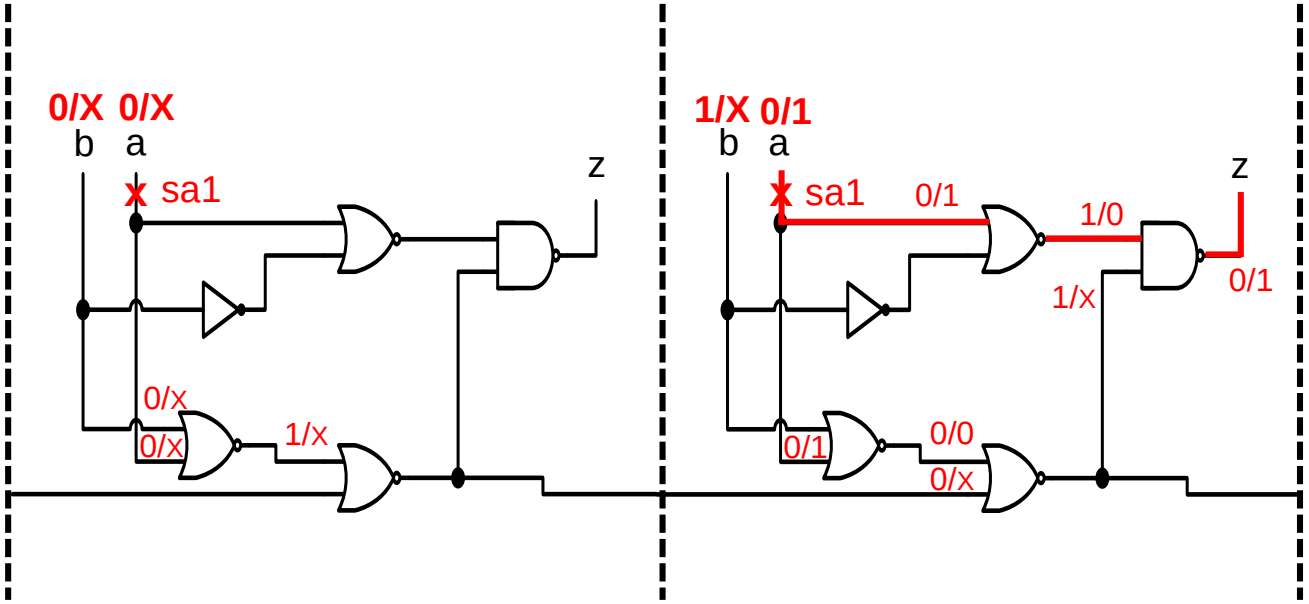
Symbol	Meaning	Roth's 5-valued logic		Muth's 9 valued logic	
		Fault-free	faulty	Fault-free	faulty
D	(1/0)	1	0	1	0
D'	(0/1)	0	1	0	1
0	(0/0)	0	0	0	0
1	(1/1)	1	1	1	1
X	(x/x)	X	X	X	X
G0	(0/x)	-	-	0	X
G1	(1/x)	-	-	1	X
F0	(x/0)	-	-	X	0
F1	(x/1)	-	-	X	1

Nine-valued Truth Table

- **Example of AND gate**

AND	0	0/x	D’	x/0	x/x	x/1	D	1/x	1
0	0	0	0	0	0	0	0	0	0
0/x	0	0/x	0/x	0	0/x	0/x	0	0/x	0/x
D’	0	0/x	D’	0	0/x	D’	0	0/x	D’
x/0	0	0	0	x/0	x/0	x/0	x/0	x/0	x/0
x/x	0	0/x	0/x	x/0	x/x	x/x	x/0	x/x	x/x
x/1	0	0/x	D’	x/0	x/x	x/1	x/0	x/x	x/1
D	0	0	0	x/0	x/0	x/0	D	D	D
1/x	0	0/x	0/x	x/0	x/x	x/x	D	1/x	1/x
1	0	0/x	D’	x/0	x/x	x/1	D	1/x	1

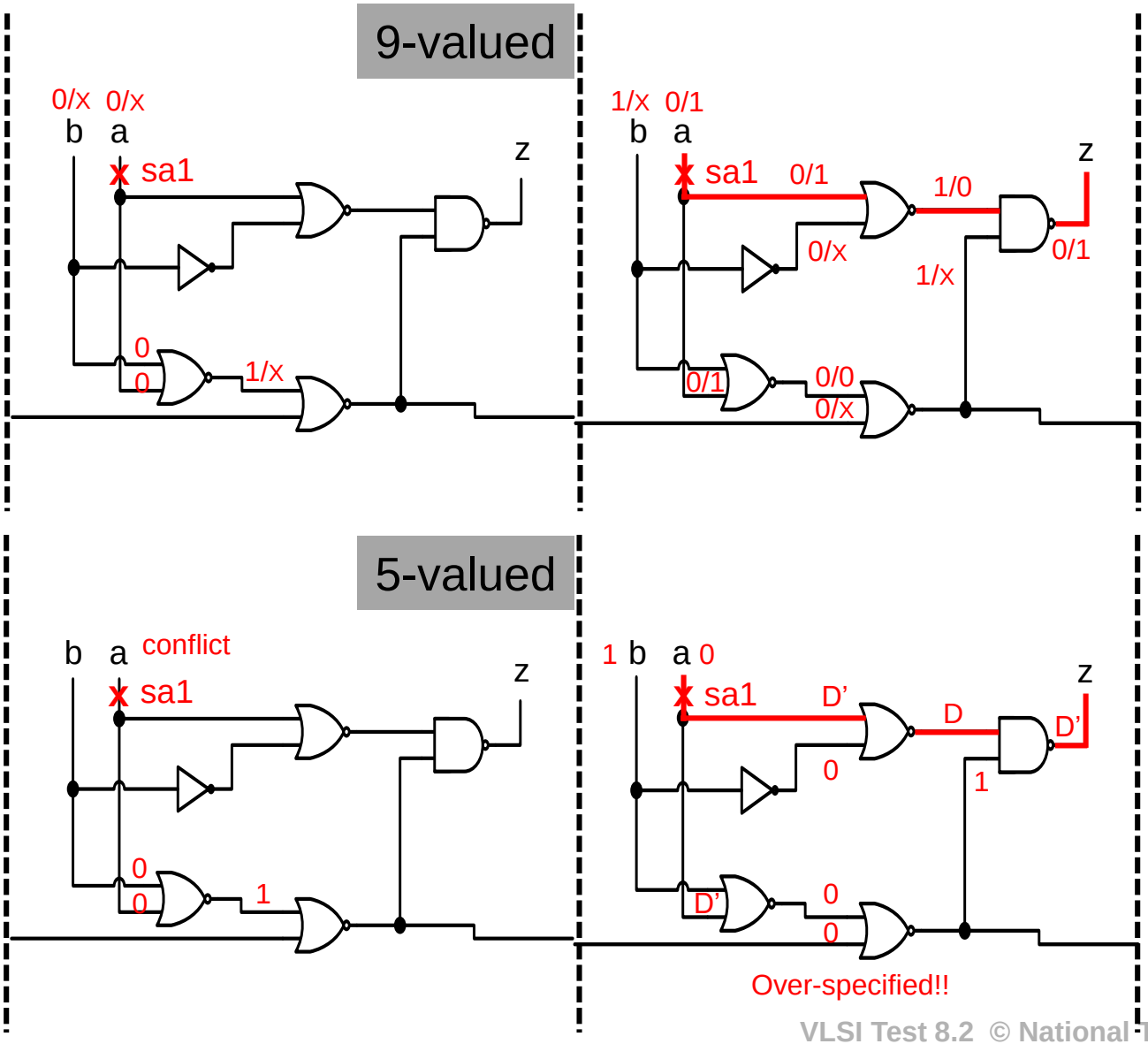
Nine-Valued Test Generation



Test pattern successfully generated

	a	b
v_1	0	0
v_2	0	1

Comparison: 9 v.s. 5 valued



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  - **9-valued D algorithm [Muth 76]**
    - **express all nine possible logic states**
    - **avoid over-specification**
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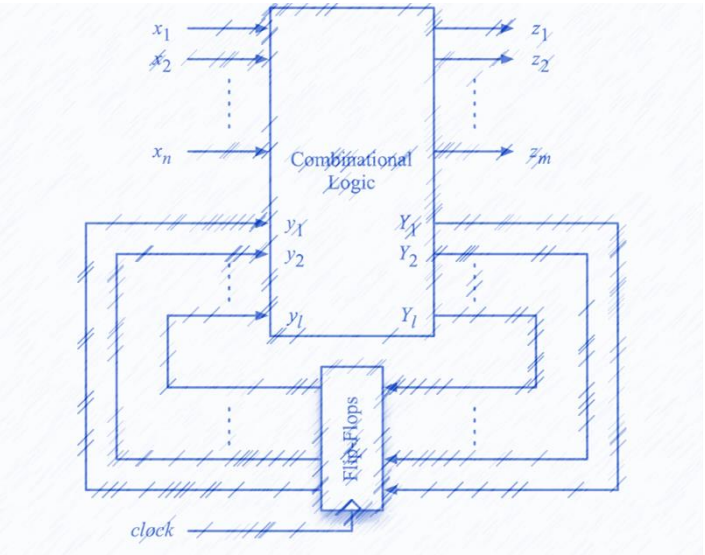

FFT

- Q1: Why NOT consider 1/x, 0/x, x/0, x/1 in combinational ATPG?
- Q2: Why NOT backtrace Y_{-1} one more time frame to the left?