

ASP Timer

STA Engine Technical Report

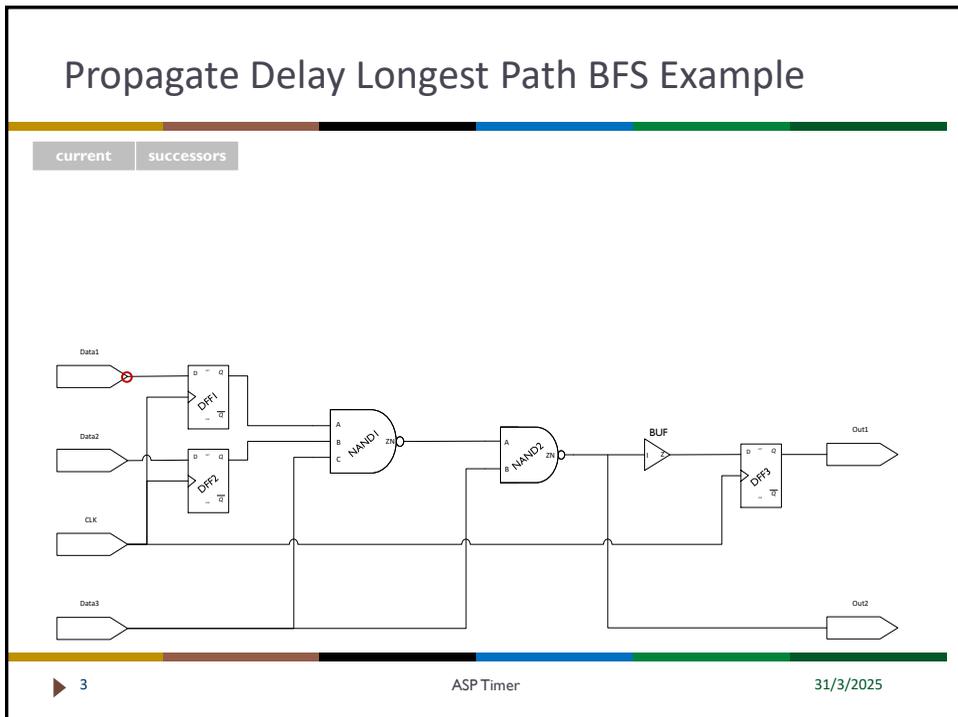
1

Propagate Delay Longest Path BFS Example

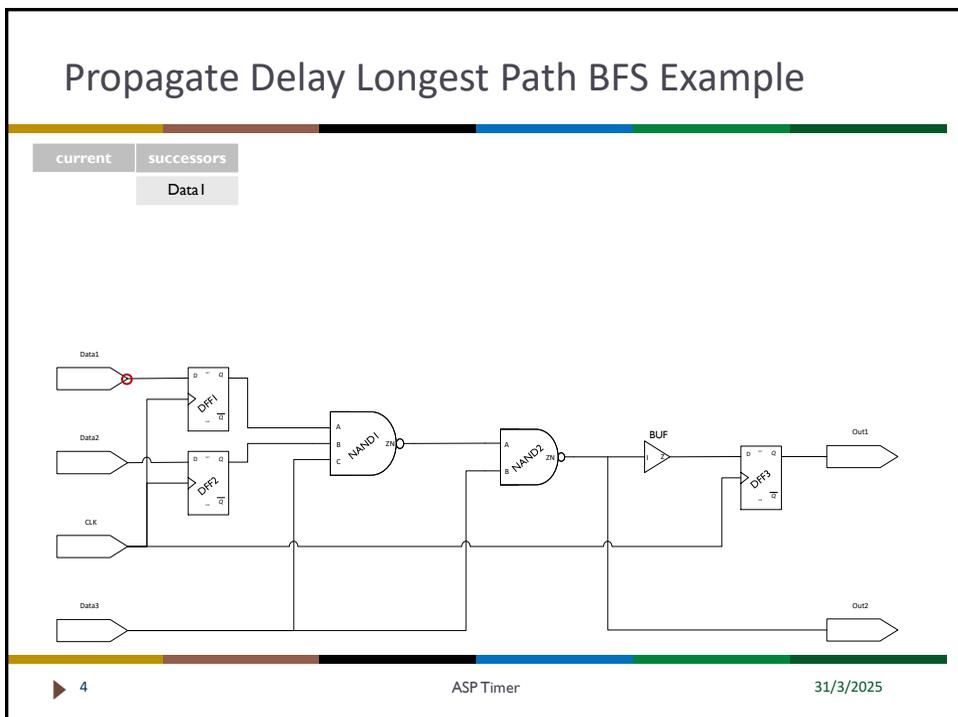
current
successors

▶ 2
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Propagate Delay Longest Path BFS Example

current	successors
	Data 1

▶ 5
ASP Timer
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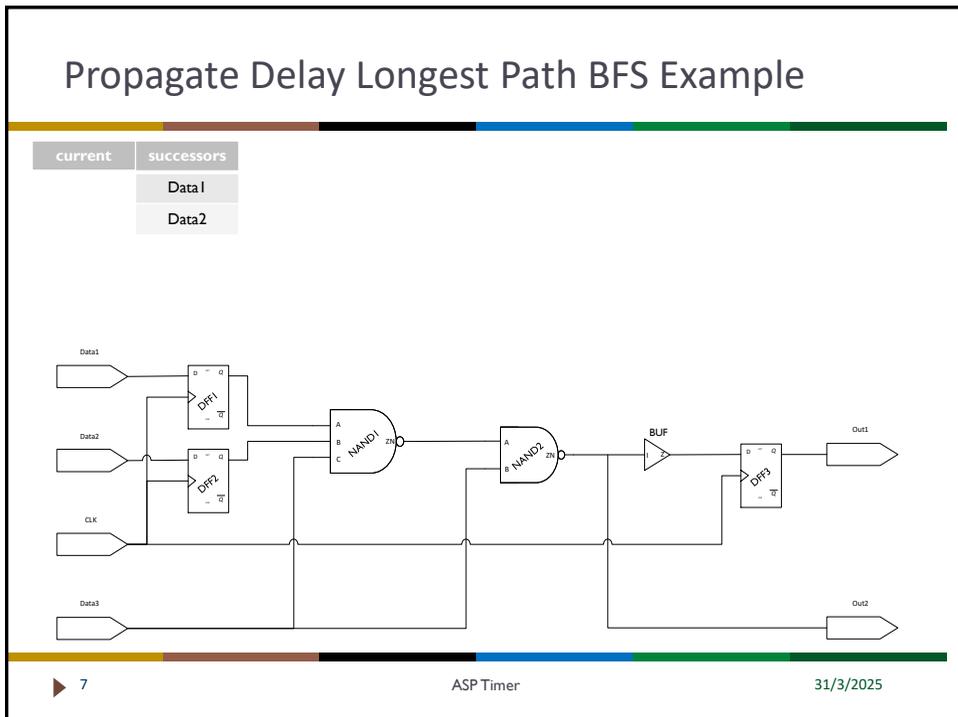
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Propagate Delay Longest Path BFS Example

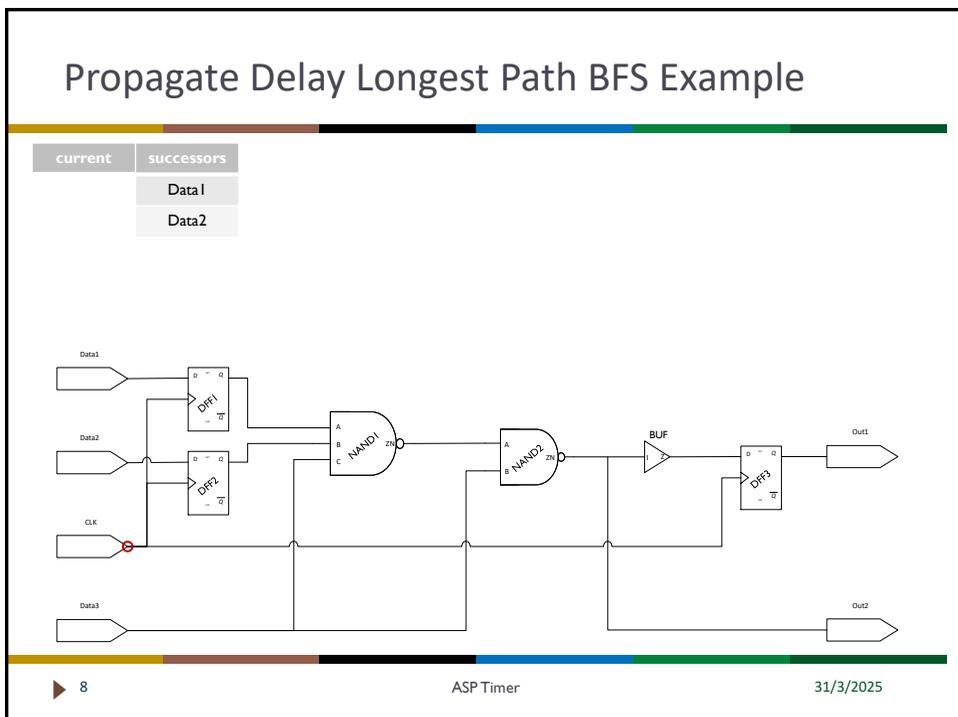
current	successors
	Data 1

▶ 6
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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3

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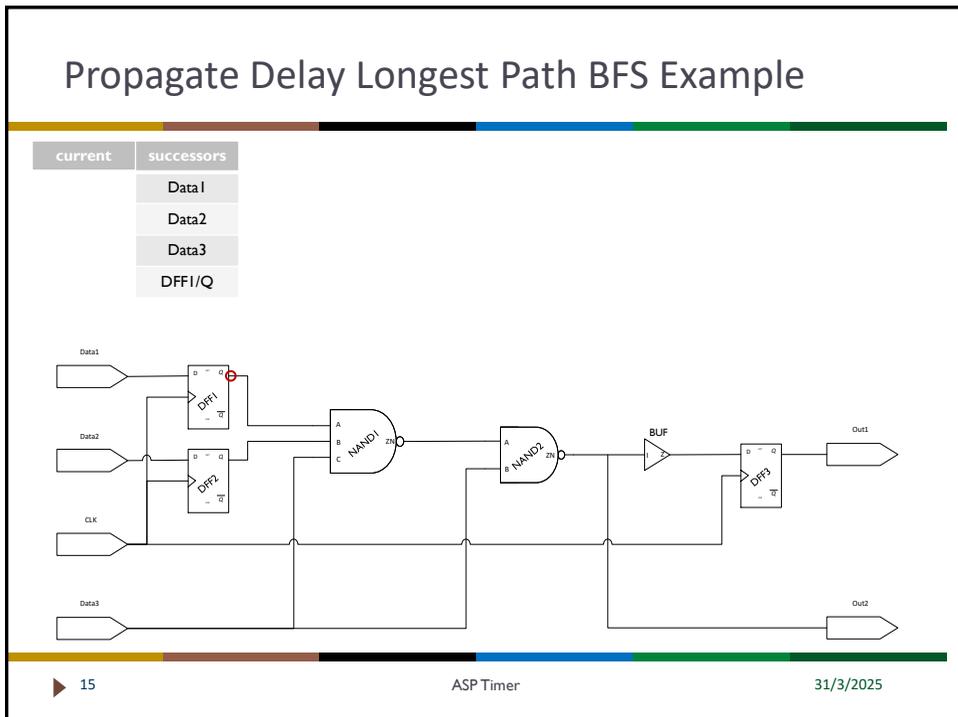
13

Propagate Delay Longest Path BFS Example

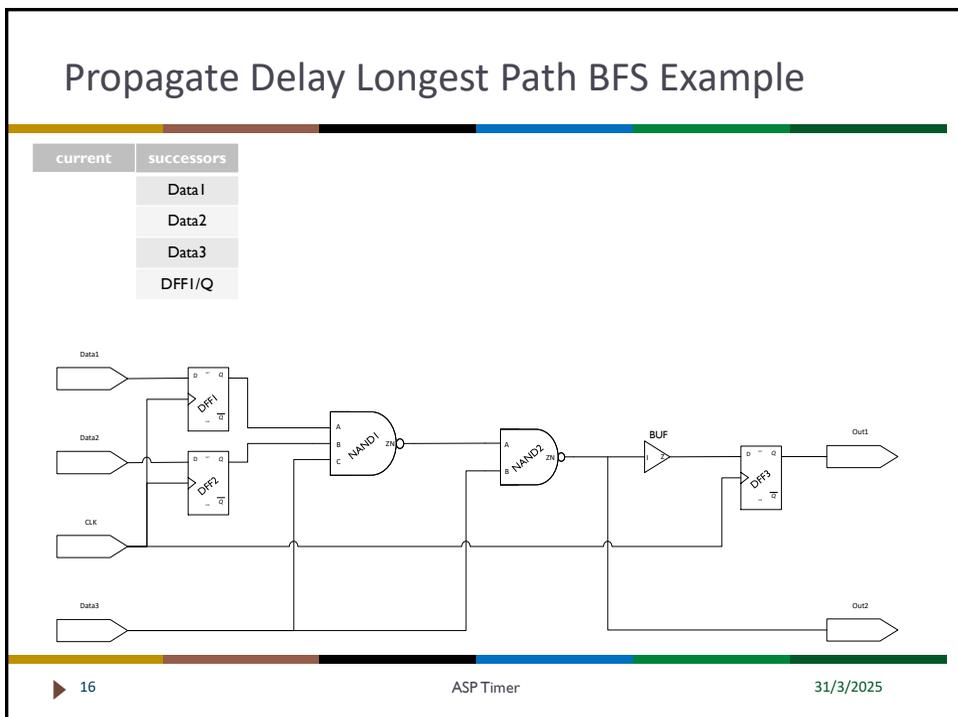
current	successors
	Data1
	Data2
	Data3

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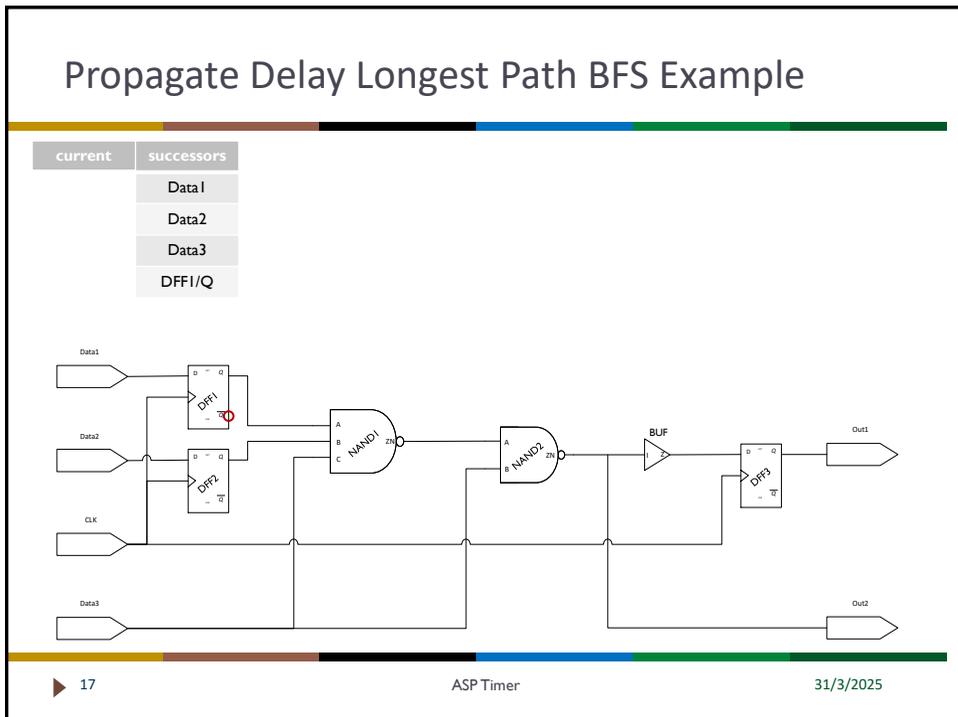
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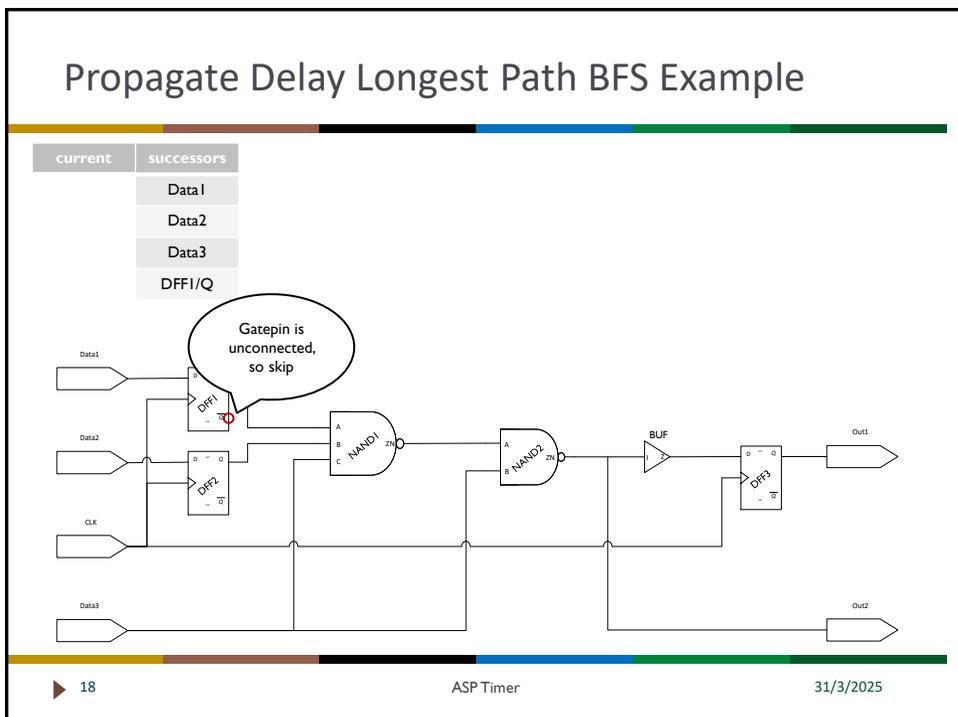
15



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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3
	DFF1/Q

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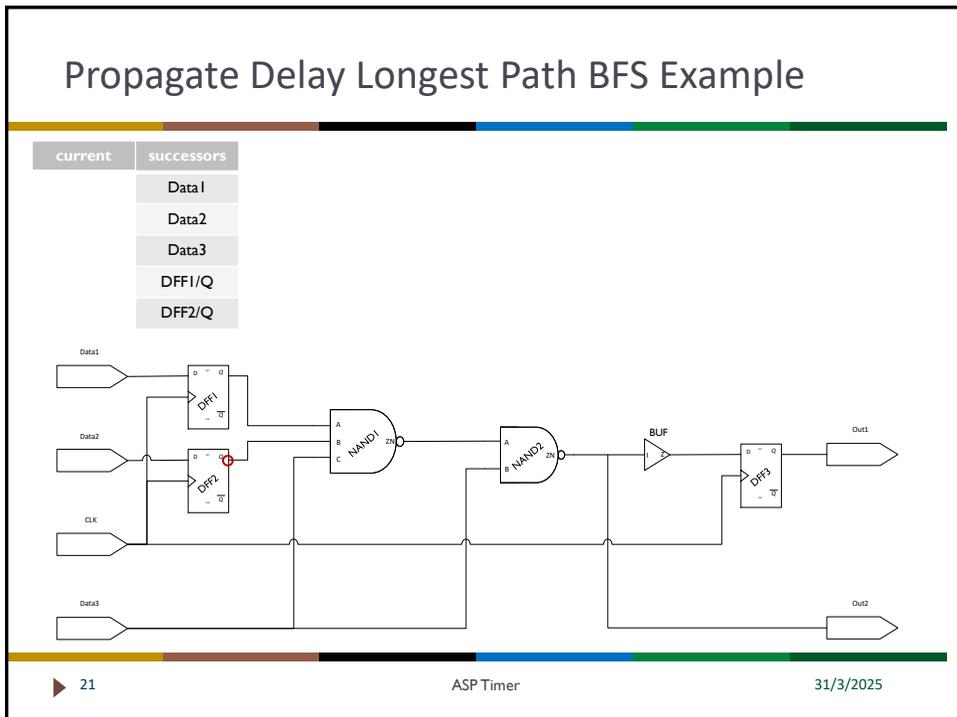
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Propagate Delay Longest Path BFS Example

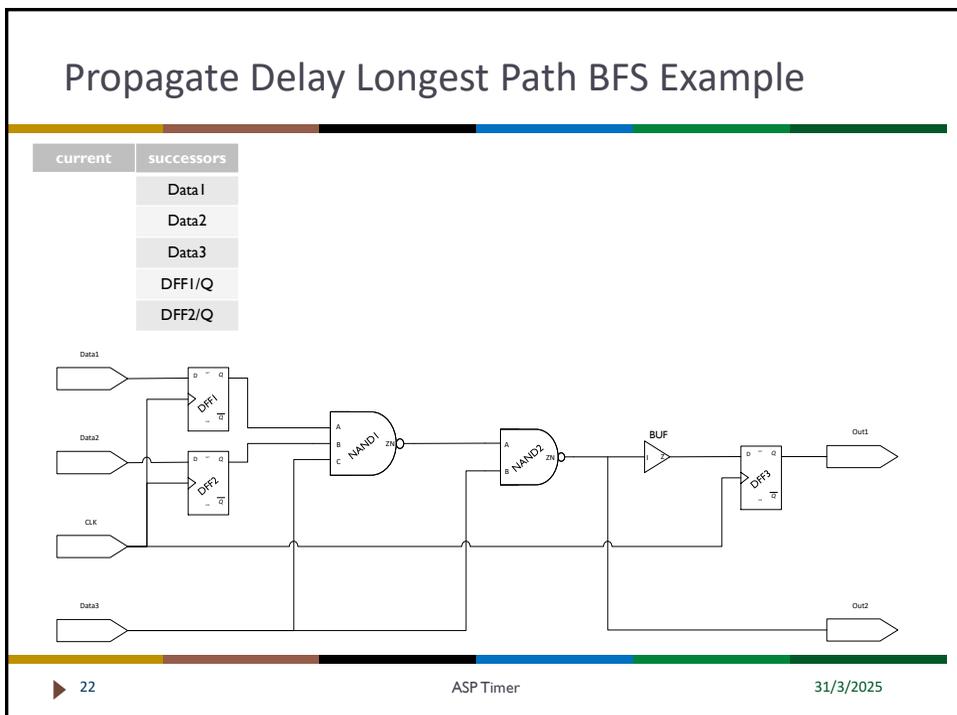
current	successors
	Data1
	Data2
	Data3
	DFF1/Q

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3
	DFF1/Q
	DFF2/Q

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3
	DFF1/Q
	DFF2/Q

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3
	DFF1/Q
	DFF2/Q

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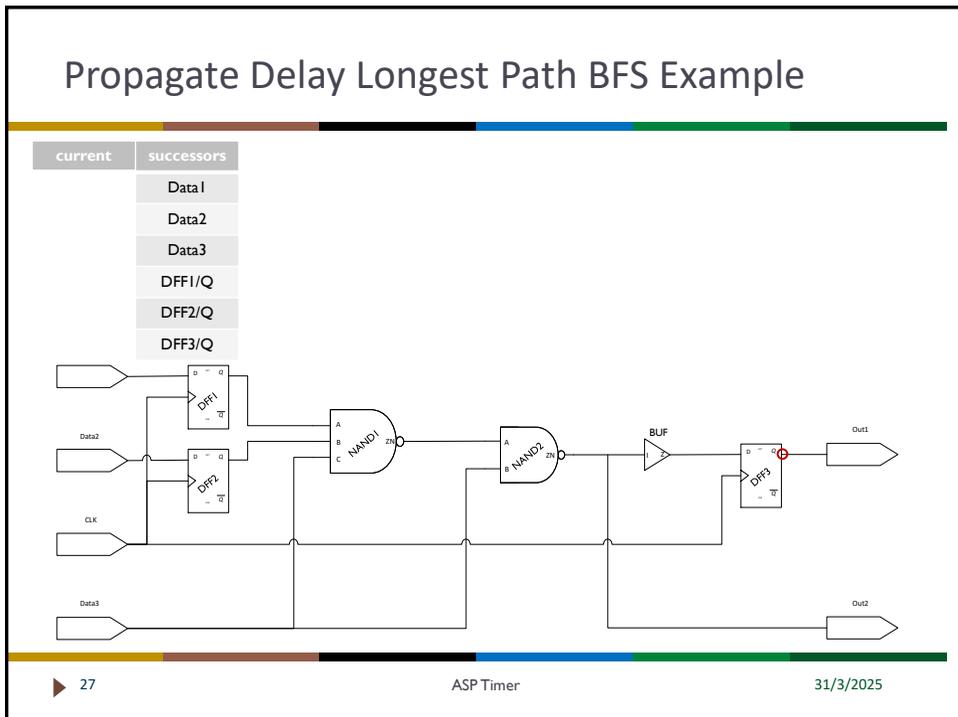
25

Propagate Delay Longest Path BFS Example

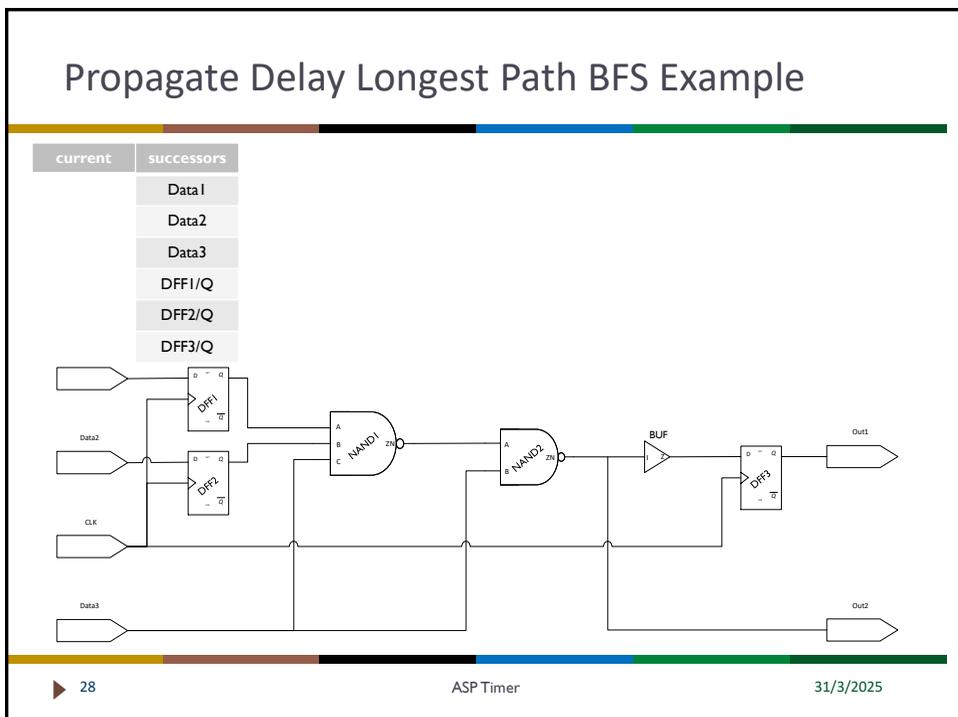
current	successors
	Data1
	Data2
	Data3
	DFF1/Q
	DFF2/Q

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3
	DFF1/Q
	DFF2/Q
	DFF3/Q

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3
	DFF1/Q
	DFF2/Q
	DFF3/Q

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Propagate Delay Longest Path BFS Example

current	successors
	Data1
	Data2
	Data3
	DFF1/Q
	DFF2/Q
	DFF3/Q

replace

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Swapping is equivalent to level increment.

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

If the PI has been constrained by an SDC command then we propagate the cell_rise, cell_fall, rise_transition and fall_transition times to the FF's input.

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

If the incoming path is been constrained and the FF pins' isconstrained field is set to 1 (FF is clocked) then we keep the isconstrained field to 1. Else set to zero (to be easily identified as unconstrained by the RAT propagation algorithm)

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

FF input gatepin is STA endpoint, so prevent adding component's outputs on successors

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

FF input gatepin is STA endpoint, so prevent adding component's outputs on successors

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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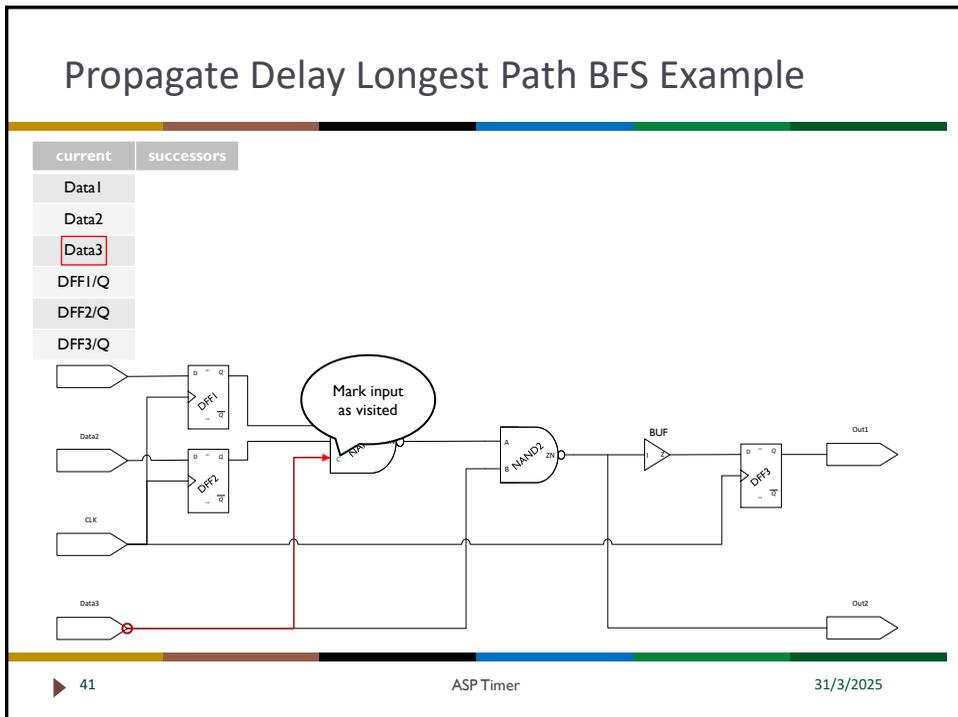
39

Propagate Delay Longest Path BFS Example

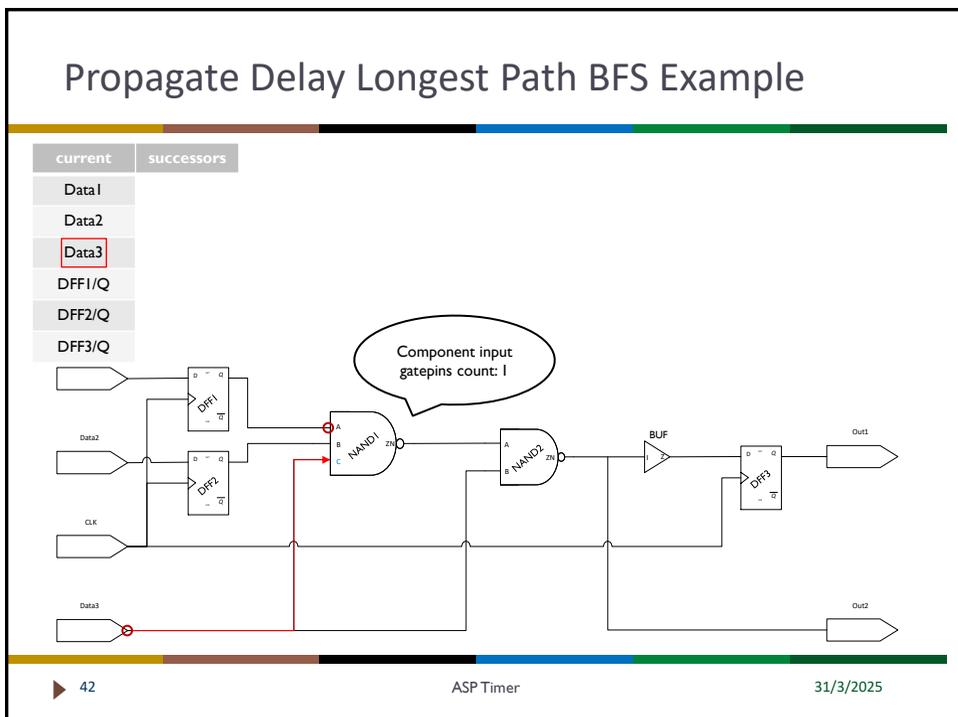
current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Input gatepin's previous connections: 1

Mark the previous connections flag on input gatepins with 1 to prevent counting the inputs every time you reach the component. That way we count the input gatepins only 1 time.

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Component input gatepins count: 2

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Mark the previous connections flag on input gatepins with 1 to prevent counting the inputs every time you reach the component. That way we count the input gatepins only 1 time.

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Component input gatepins count: 3

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Mark the previous connections flag on input gatepins with 1 to prevent counting the inputs every time you reach the component. That way we count the input gatepins only 1 time.

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Prev inputs = 3
Prev visited inputs = 1

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Component input gatepins count: 1

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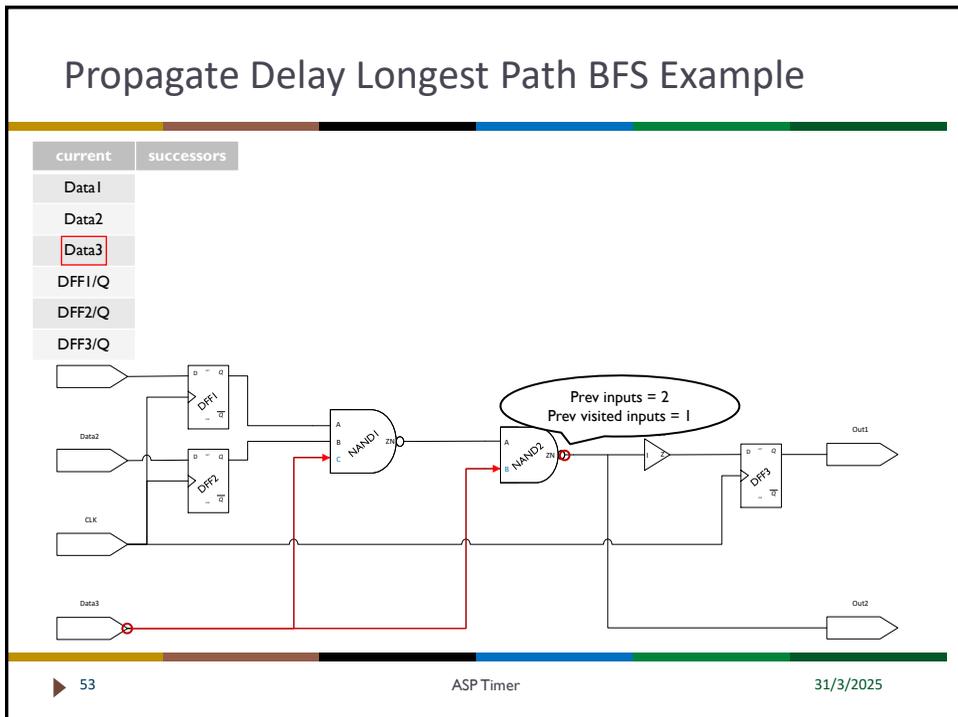
Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

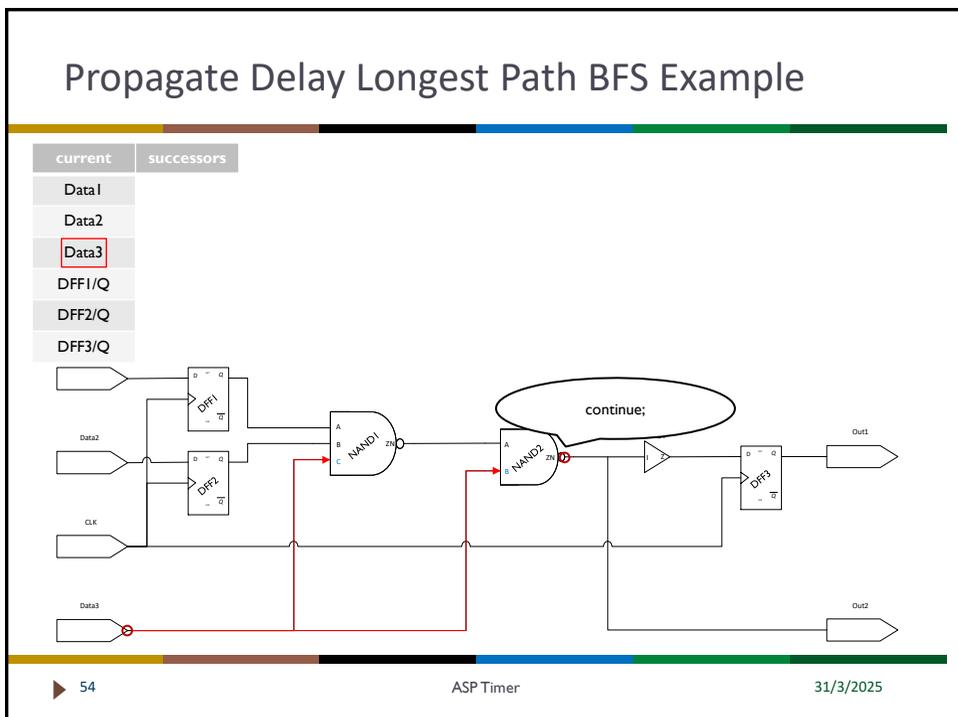
Component input gatepins count: 2

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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Propagate Delay Longest Path BFS Example

current	successors
Data1	
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Prev inputs = 3
Prev visited inputs = 3

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Propagate Delay Longest Path BFS Example

current	successors
Data1	NAND1/ZN
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

Insert to successors

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Propagate Delay Longest Path BFS Example

current	successors
Data1	NAND1/ZN
Data2	
Data3	
DFF1/Q	
DFF2/Q	
DFF3/Q	

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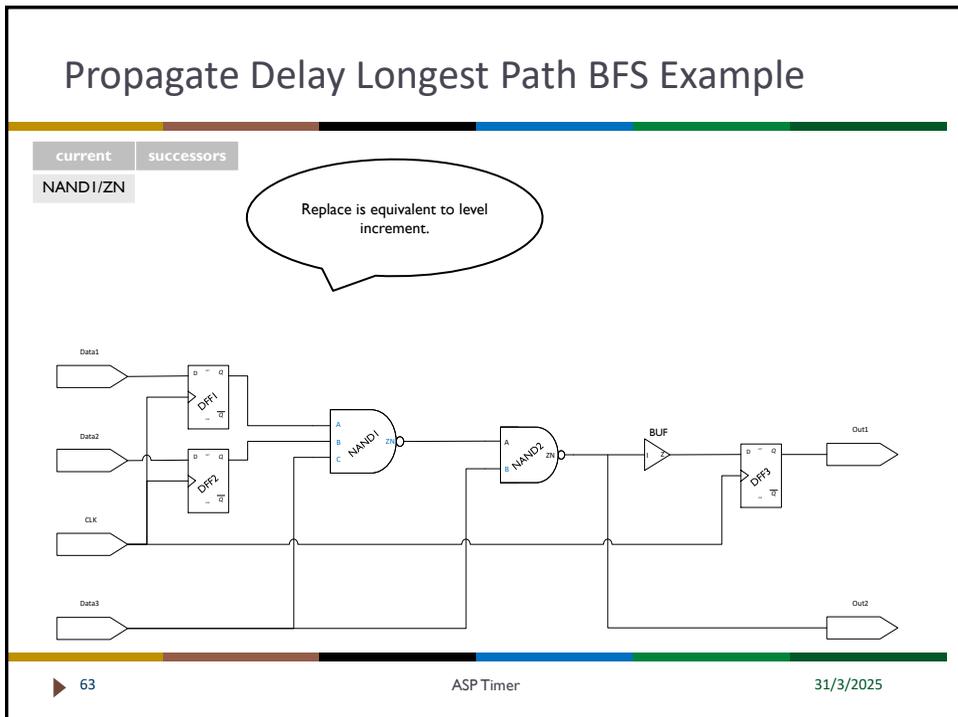
Propagate Delay Longest Path BFS Example

current	successors
Data1	NAND1/ZN
Data2	
DFF1/Q	
DFF2/Q	
DFF3/Q	

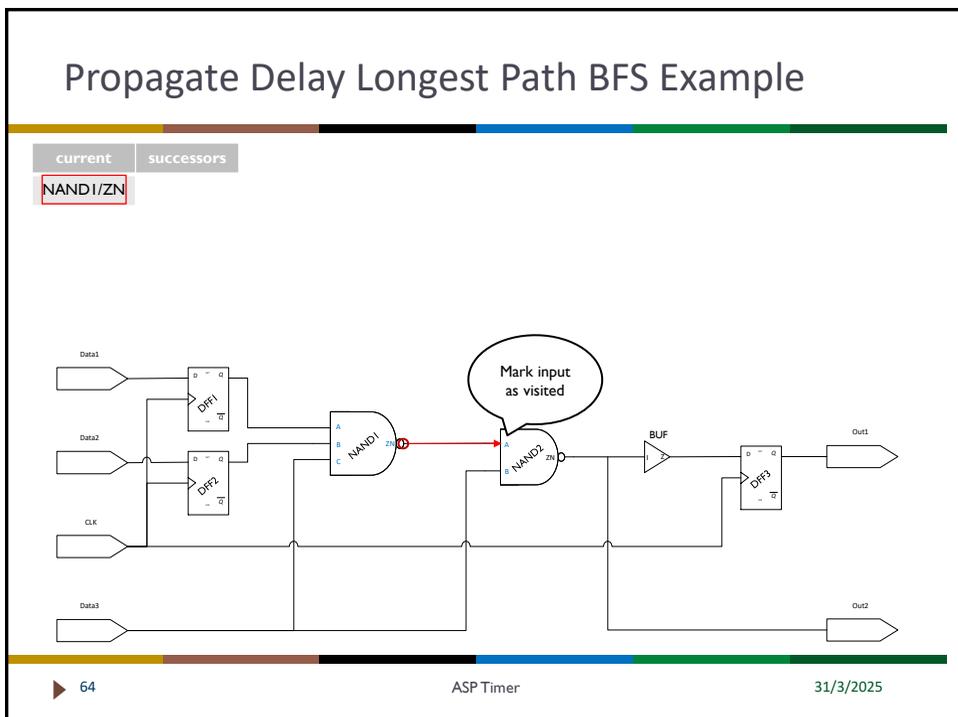
replace

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Propagate Delay Longest Path BFS Example

current	successors
NAND1/ZN	

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Propagate Delay Longest Path BFS Example

current	successors
NAND1/ZN	NAND2/ZN

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Propagate Delay Longest Path BFS Example

current	successors
NAND1/ZN	NAND2/ZN

Reached last current output so free current array and replace it with successors

replace

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Propagate Delay Longest Path BFS Example

current	successors
NAND2/ZN	

Replace is equivalent to level increment.

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Propagate Delay Longest Path BFS Example

current
successors

NAND2/ZN

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Propagate Delay Longest Path BFS Example

current
successors

NAND2/ZN

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Propagate Delay Longest Path BFS Example

current	successors
NAND2/ZN	BUF/Z

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Propagate Delay Longest Path BFS Example

current	successors
NAND2/ZN	BUF/Z

replace

Reached last current output so free current array and replace it with successors

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Propagate Delay Longest Path BFS Example

current

successors

BUF/Z

Replace is equivalent to level increment.

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ASP Timer
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Propagate Delay Longest Path BFS Example

current

successors

BUF/Z

FF input gatepin is STA endpoint, so prevent adding component's outputs on successors

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Propagate Delay Longest Path BFS Example

current

successors

BUF/Z

Reached last current output so free current array and replace it with successors

replace

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Propagate Delay Longest Path BFS Example

current

successors

Replace is equivalent to level increment.

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Propagate Delay Longest Path BFS Example

current
successors

Current array is empty after replace. Delay propagation algorithm has finished.

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Propagate RAT Longest Path BFS Example

predecessors
current

PO's unconstrained field was not set to 1 by an SDC command, so skip

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Propagate RAT Longest Path BFS Example

predecessors
current

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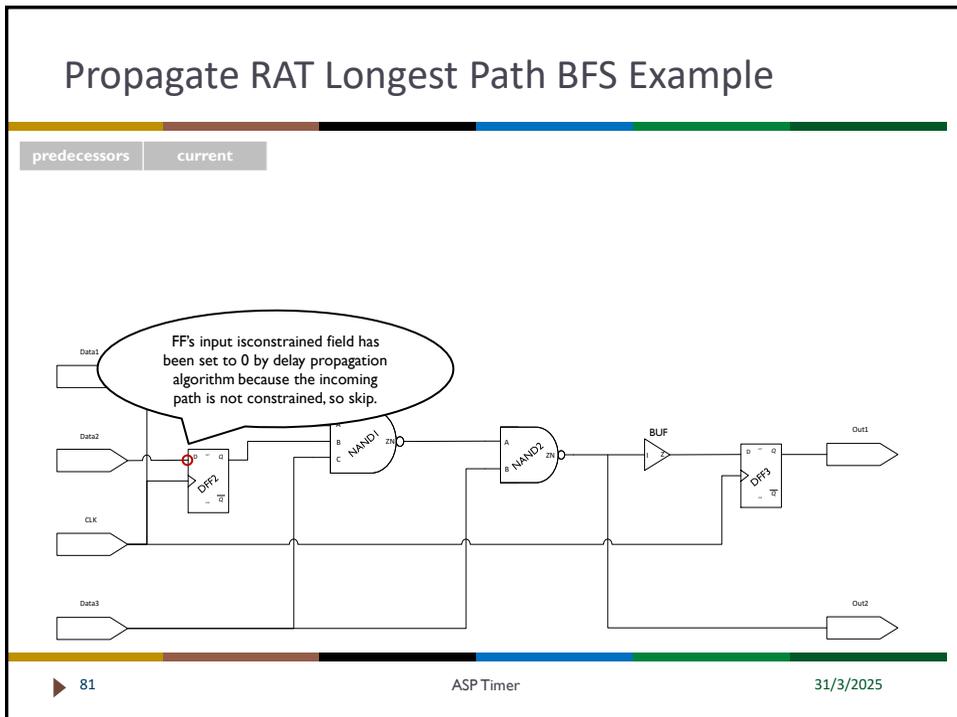
79

Propagate RAT Longest Path BFS Example

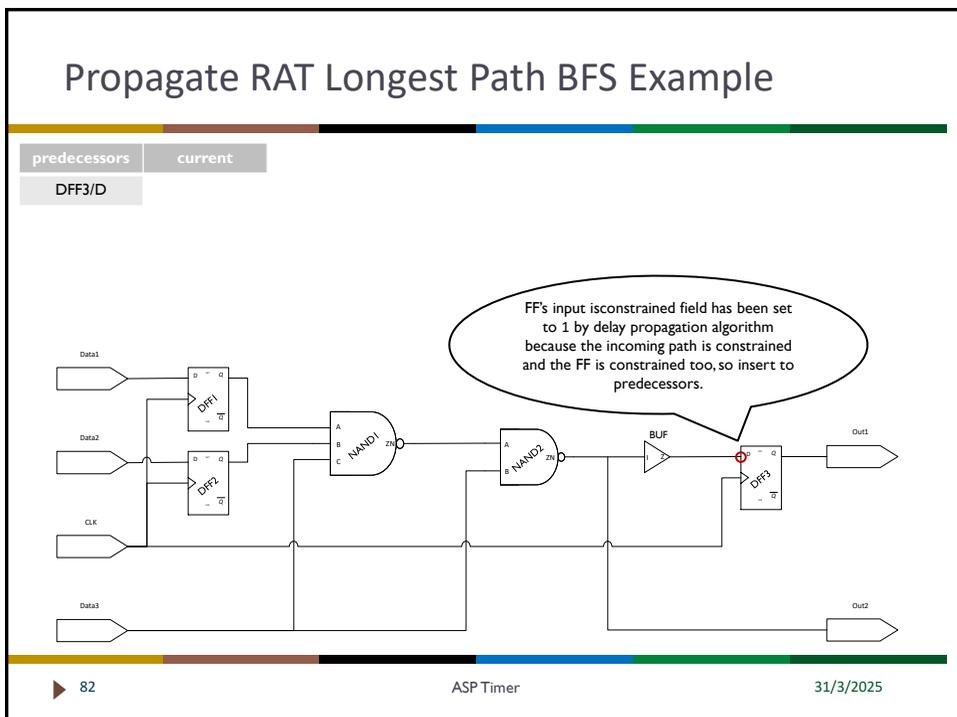
predecessors
current

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Propagate RAT Longest Path BFS Example

predecessors	current
DFF3/D	

replace

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Propagate RAT Longest Path BFS Example

predecessors	current
DFF3/D	

Replace is equivalent to level increment on the Transpose Graph.

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Propagate RAT Longest Path BFS Example

predecessors	current
	DFF3/D

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Propagate RAT Longest Path BFS Example

predecessors	current
	DFF3/D

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Propagate RAT Longest Path BFS Example

predecessors	current
	DFF3/D

Fanout cone : 1
Visited count : 1

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Propagate RAT Longest Path BFS Example

predecessors	current
	DFF3/D

Prev outputs count : 1
Prev visited outputs count : 1

Identically with delay propagation algorithm we count the previous gatepins to add an input to predecessors only if every output gatepin of the same component has been visited.

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Propagate RAT Longest Path BFS Example

predecessors	current
BUF/I	DFF3/D

Insert to predecessors.

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Propagate RAT Longest Path BFS Example

predecessors	current
BUF/I	DFF3/D

Reached last current input
so free current array and
replace it with predecessors

replace

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Propagate RAT Longest Path BFS Example

predecessors	current
	BUF/I

Replace is equivalent to level increment on the Transpose Graph.

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ASP Timer
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91

Propagate RAT Longest Path BFS Example

predecessors	current
	BUF/I

Fanout connections number has been stored by delay propagation algorithm. It also sets visited connections count to 0.

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Propagate RAT Longest Path BFS Example

predecessors	current
	BUF/I

Every time we visit an output we increment the visited count. When visited equals fanout then we discover the predecessor inputs.

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Propagate RAT Longest Path BFS Example

predecessors	current
	BUF/I

Note that gatepin NAND2/ZN fanouts to Primary Output Out2, too, but we consider only component gatepins on the BFS counts.

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Propagate RAT Longest Path BFS Example

predecessors	current
	BUF/I

Identically with delay propagation algorithm we count the previous gatepins to add an input to predecessors only if every output gatepin of the same component has been visited.

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Propagate RAT Longest Path BFS Example

predecessors	current
NAND2/A	BUF/I

Insert to predecessors.

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Propagate RAT Longest Path BFS Example

predecessors	current
NAND2/A	BUF/I

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Propagate RAT Longest Path BFS Example

predecessors	current
NAND2/A	BUF/I

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98

Propagate RAT Longest Path BFS Example

predecessors	current
	NAND2/A

Replace is equivalent to level increment on the Transpose Graph.

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Propagate RAT Longest Path BFS Example

predecessors	current
	NAND2/A

Fanout connections number has been stored by delay propagation algorithm. It also sets visited connections count to 0.

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Propagate RAT Longest Path BFS Example

predecessors	current
	NAND2/A

Every time we visit an output we increment the visited count. When visited equals fanout then we discover the predecessor inputs.

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Propagate RAT Longest Path BFS Example

predecessors	current
	NAND2/A

Identically with delay propagation algorithm we count the previous gatepins to add an input to predecessors only if every output gatepin of the same component has been visited.

Prev outputs count: 1
Prev visited outputs count: 1

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Propagate RAT Longest Path BFS Example

predecessors	current
NAND1/A	NAND2/A

Insert to predecessors.

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Propagate RAT Longest Path BFS Example

predecessors	current
NAND1/A	NAND2/A

Identically with delay propagation algorithm we count the previous gatepins to add an input to predecessors only if every output gatepin of the same component has been visited.

Prev outputs count: 1
Prev visited outputs count: 1

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Propagate RAT Longest Path BFS Example

predecessors	current
NAND1/A	NAND2/A
NAND1/B	

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Propagate RAT Longest Path BFS Example

predecessors	current
NAND1/A	NAND2/A
NAND1/B	

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Propagate RAT Longest Path BFS Example

predecessors	current
NAND1/A	NAND2/A
NAND1/B	

Reached last current input
so free current array and
replace it with predecessors

replace

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Propagate RAT Longest Path BFS Example

predecessors	current
	NAND1/A
	NAND1/B

Reached FF output. RAT
propagation endpoint.

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Propagate RAT Longest Path BFS Example

predecessors	current
	NAND1/A
	NAND1/B

Reached FF output. RAT propagation endpoint.

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Propagate RAT Longest Path BFS Example

predecessors	current
	NAND1/A
	NAND1/B

replace

Reached last current input so free current array and replace it with predecessors

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Propagate RAT Longest Path BFS Example

predecessors
current

Current array is empty after replace. RAT propagation algorithm has finished.

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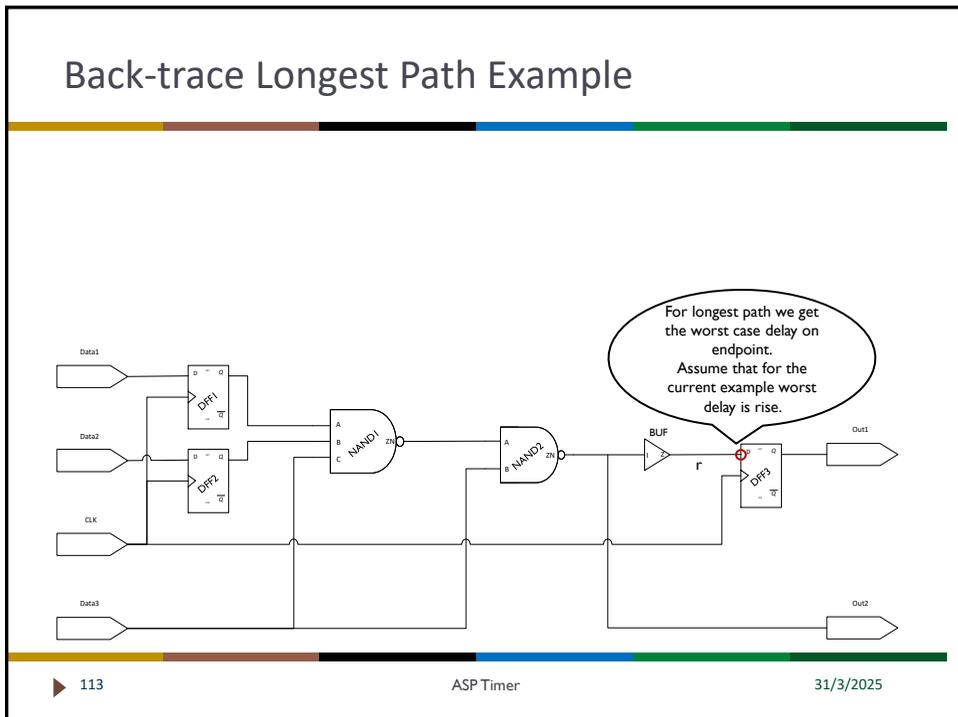
111

Back-trace Longest Path Example

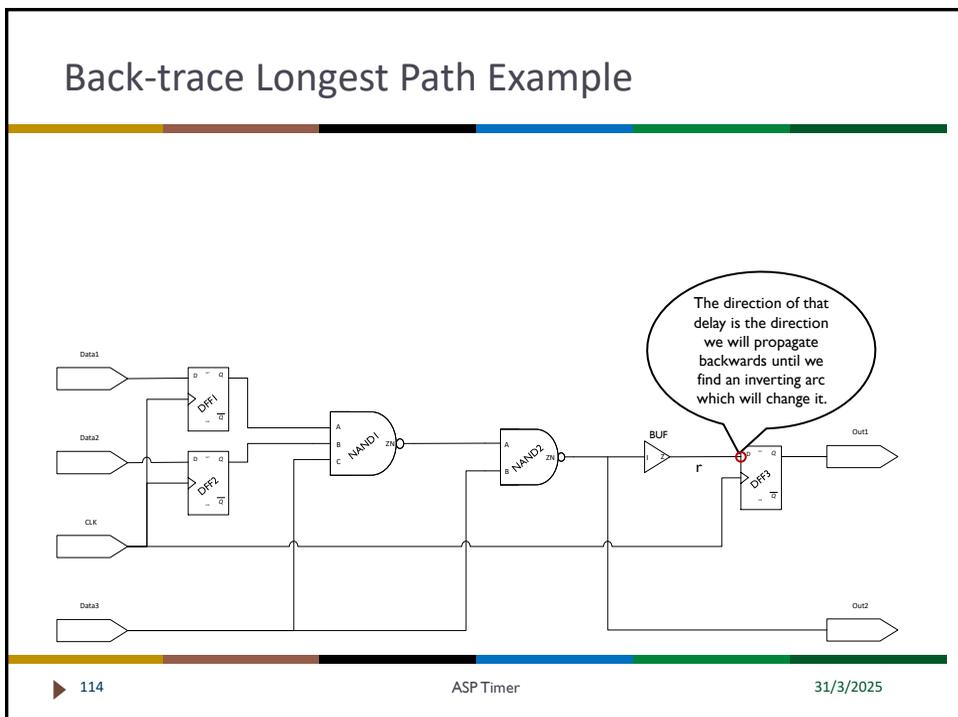
Assume gatepin DFF3/D has been found as the minimum slack path endpoint.

▶ 112
ASP Timer
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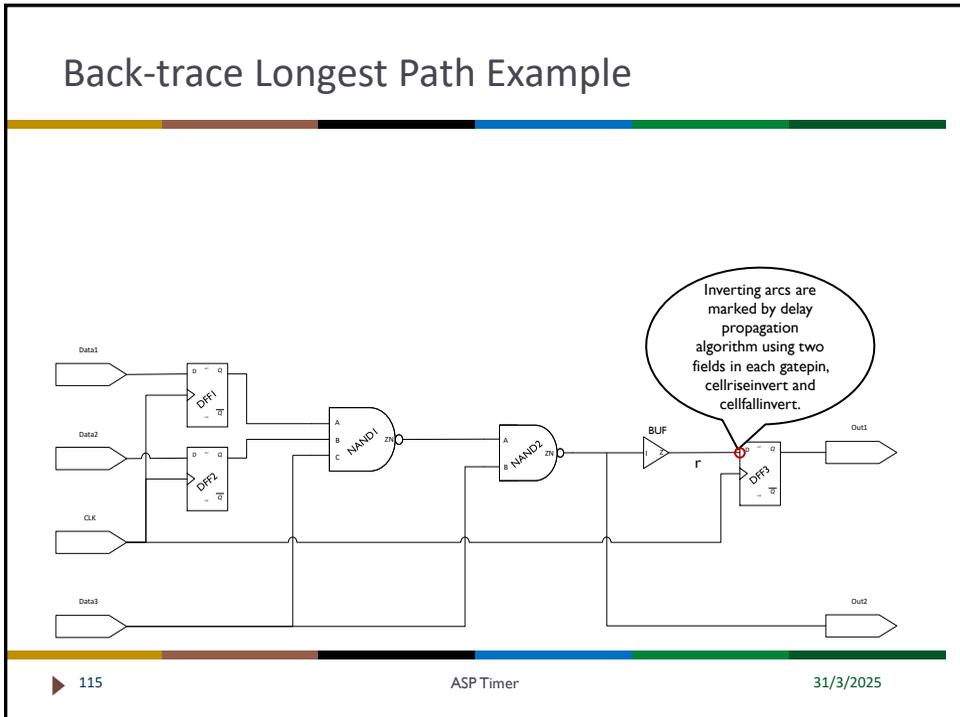
112



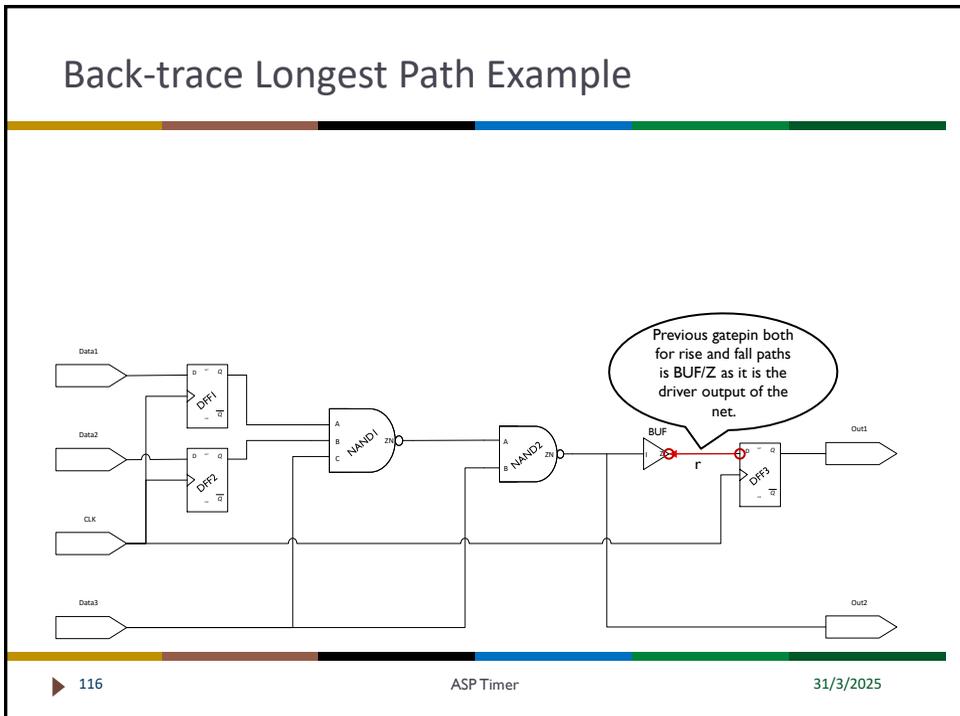
113



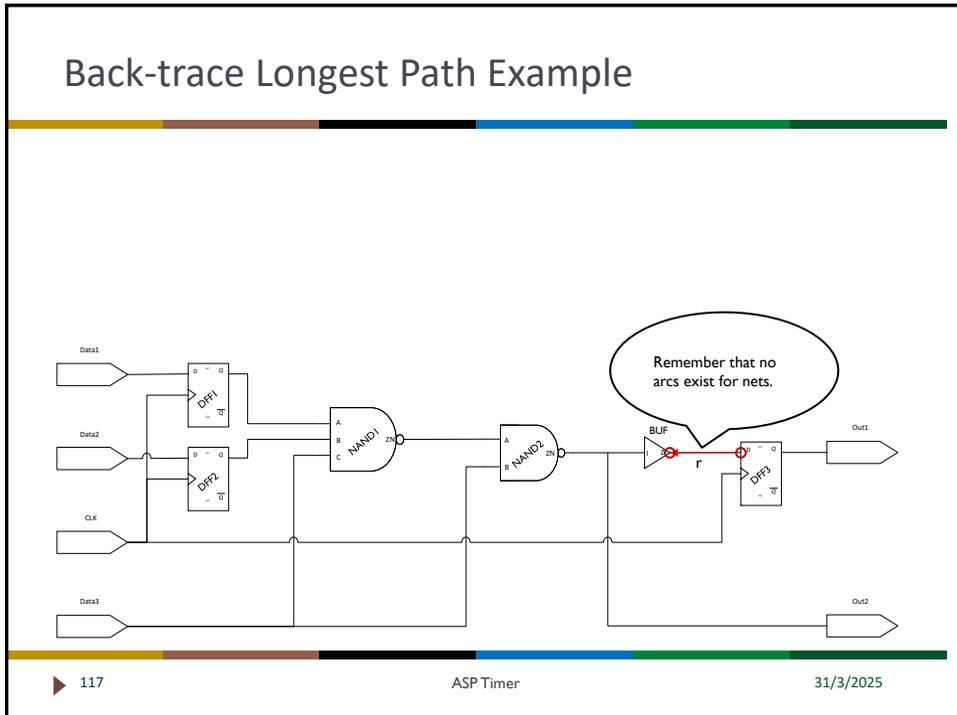
114



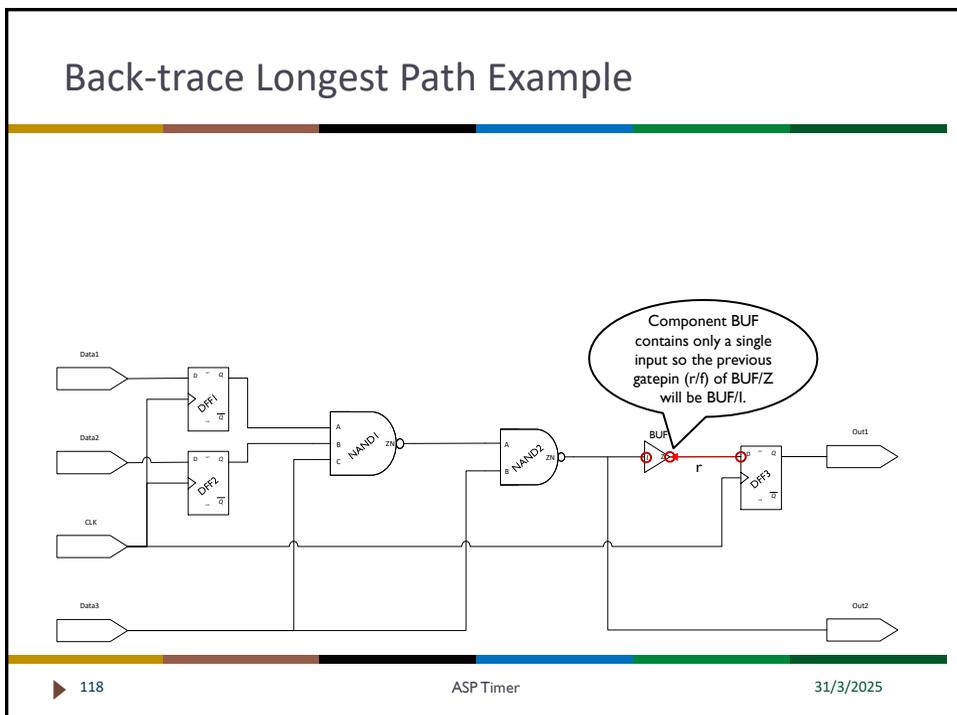
115



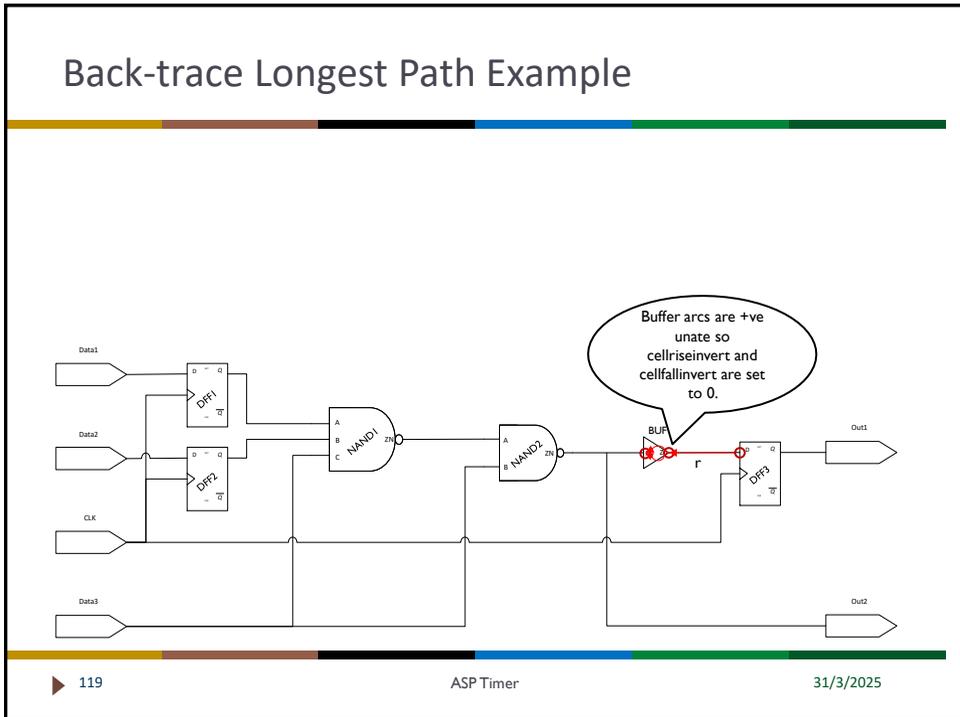
116



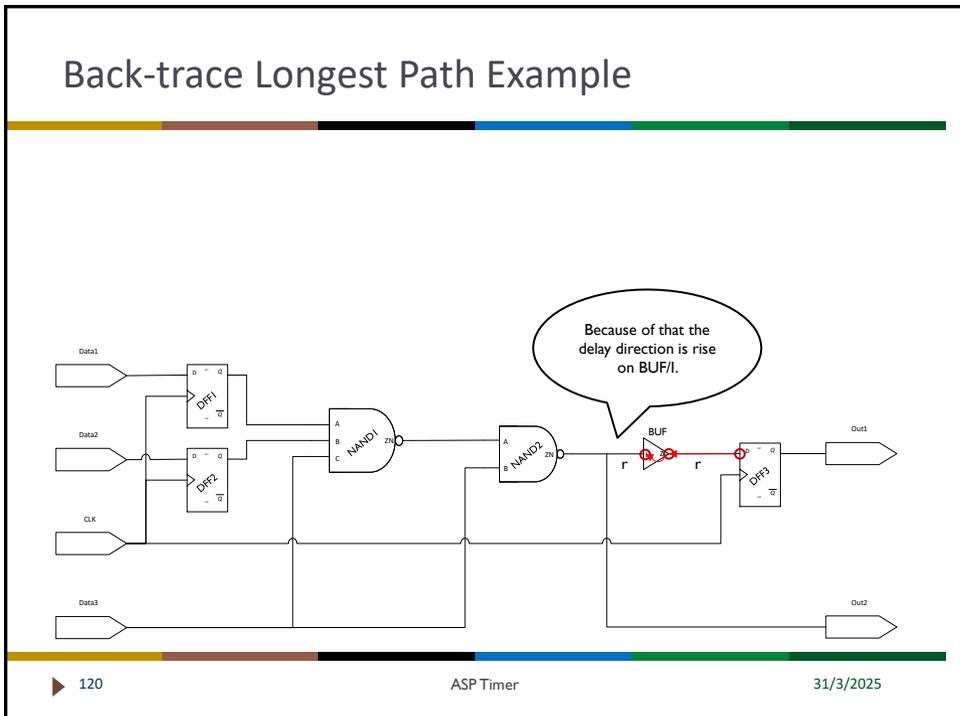
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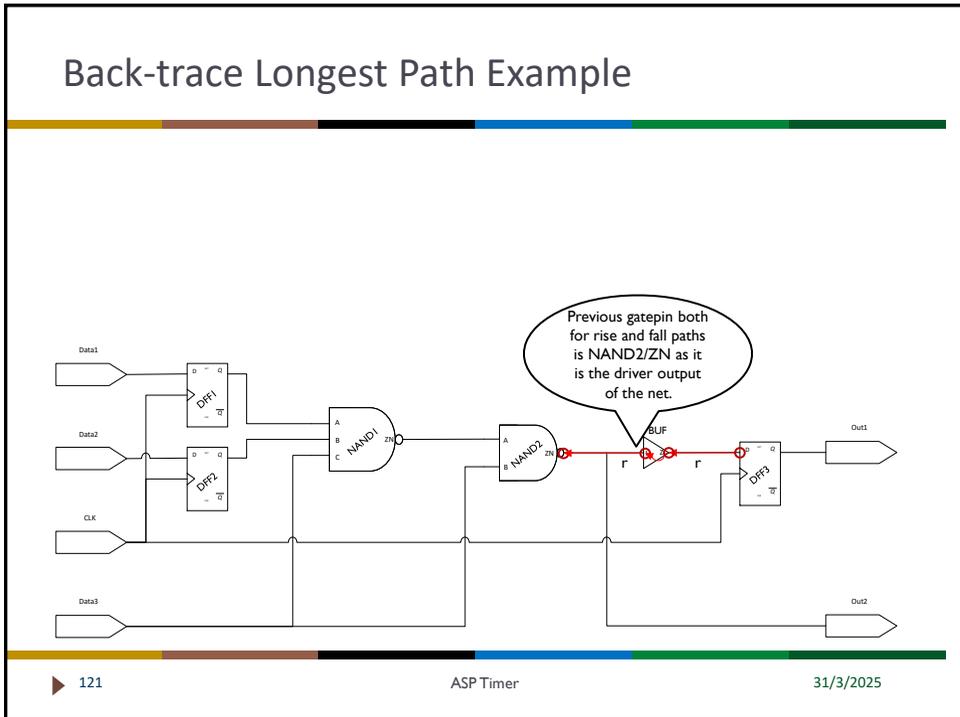
118



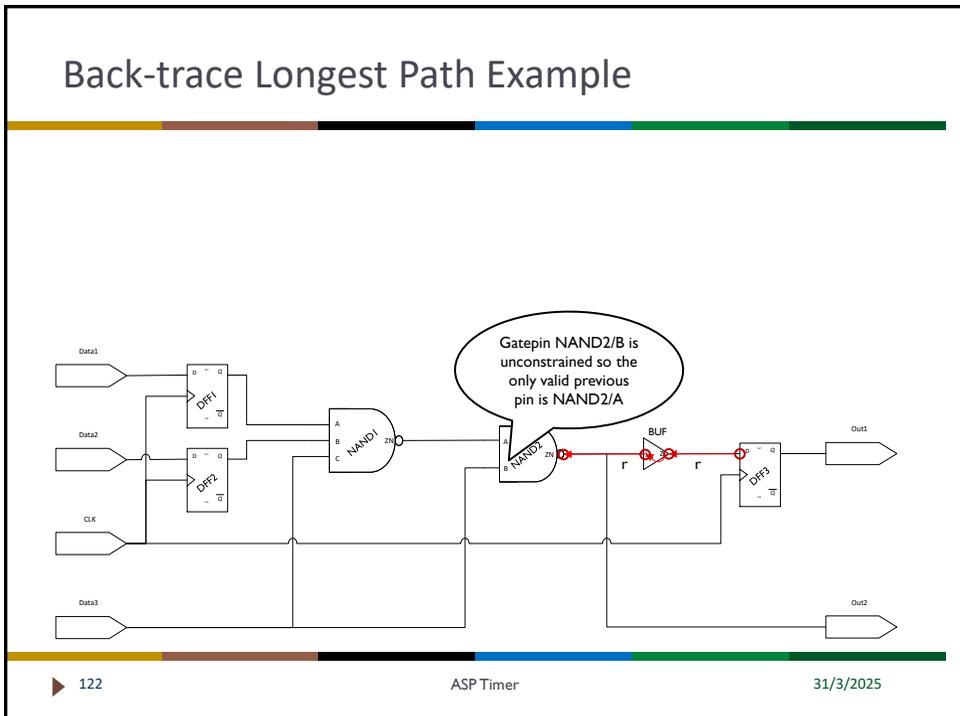
119



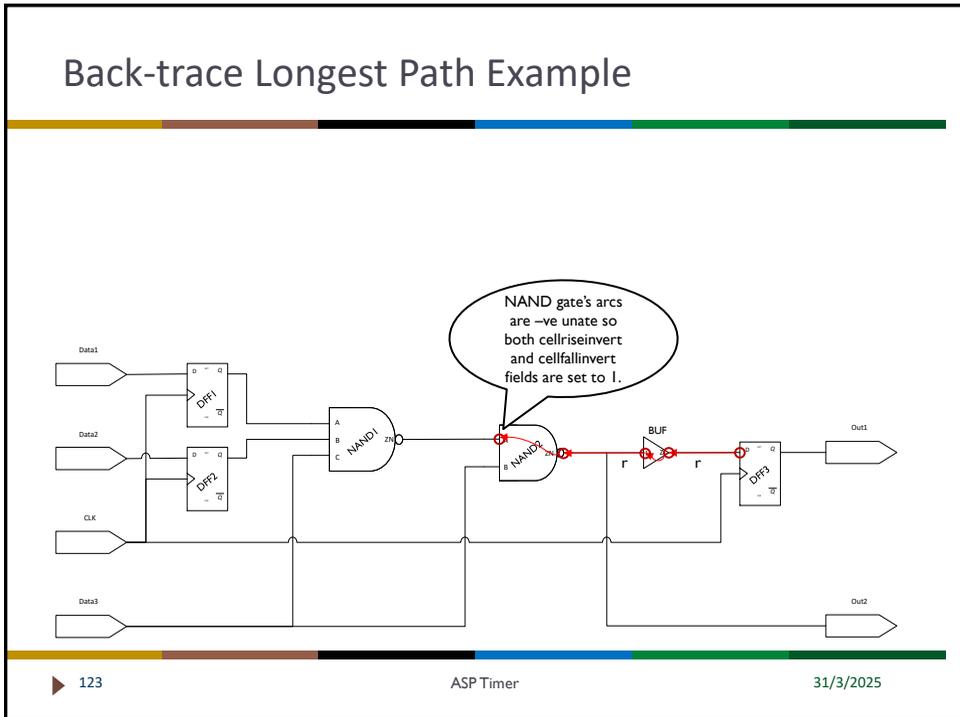
120



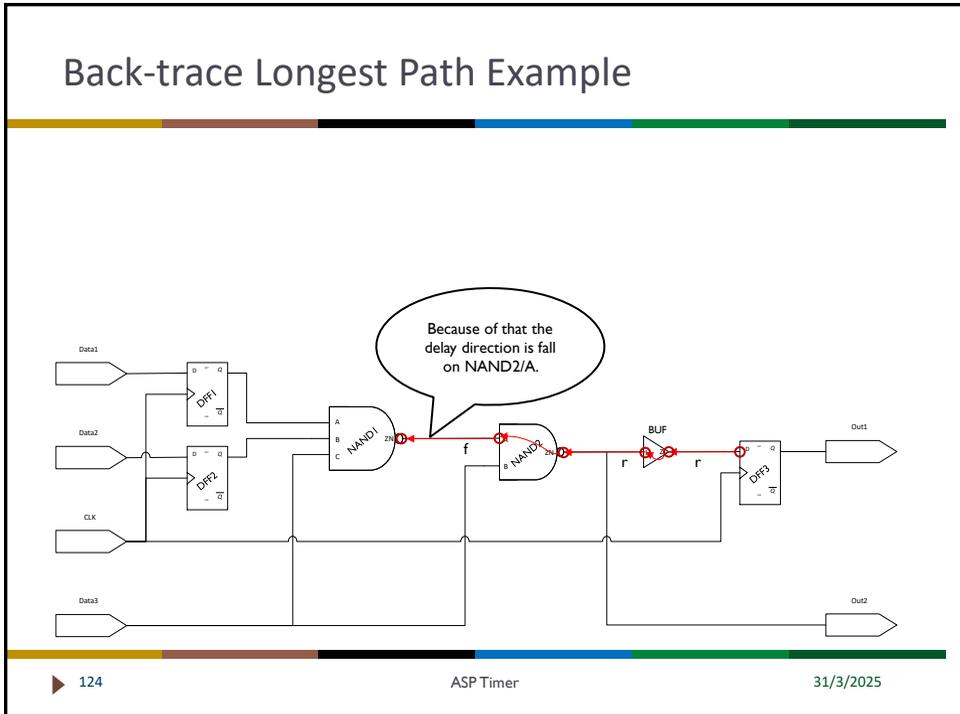
121



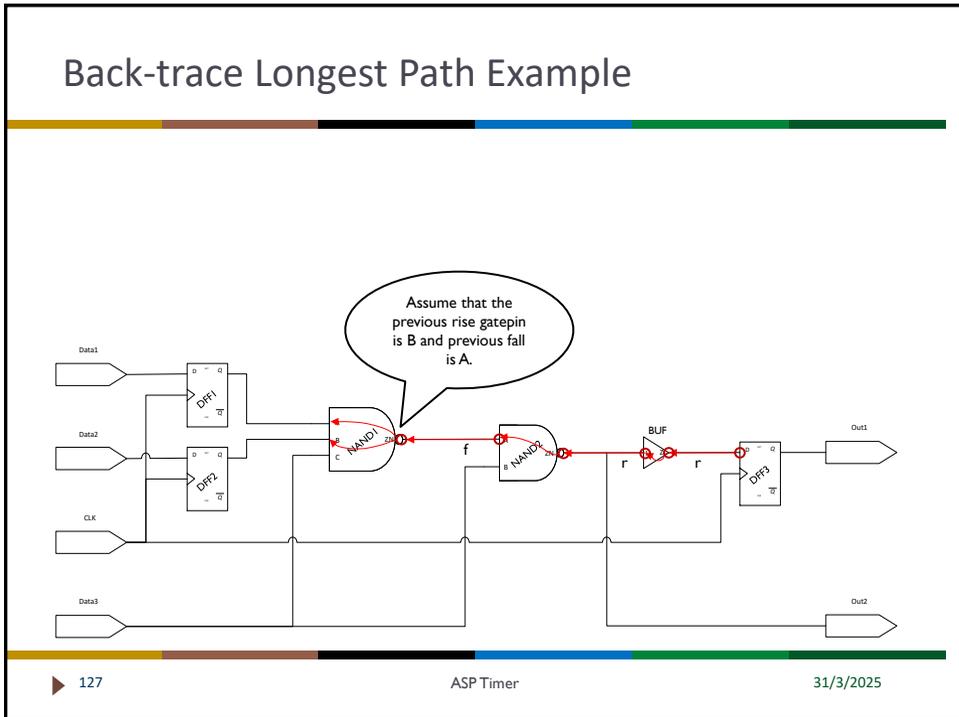
122



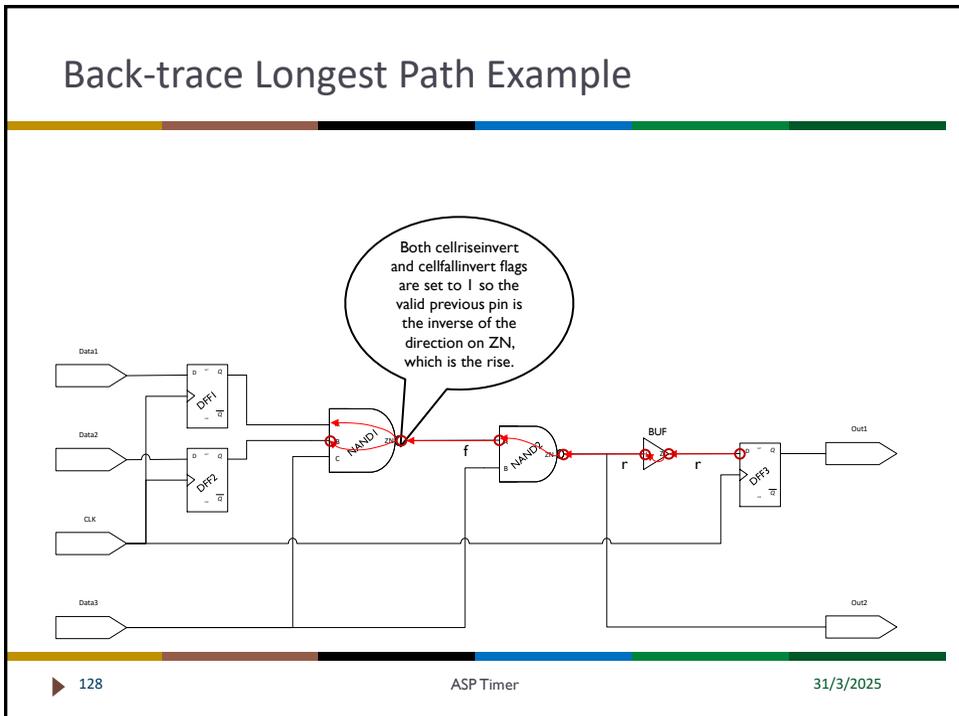
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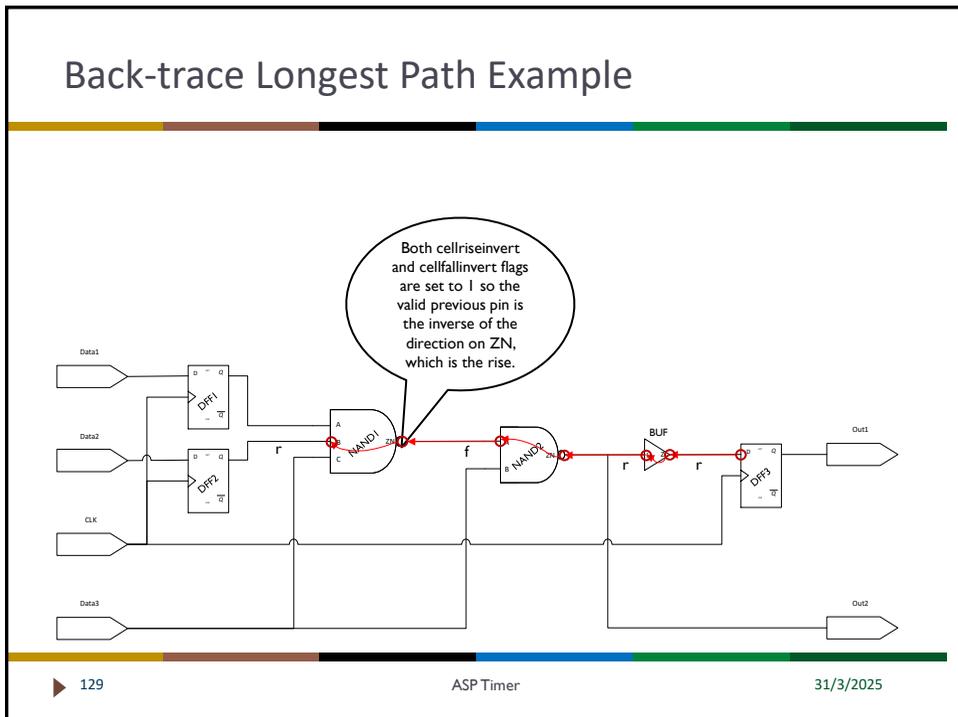
124



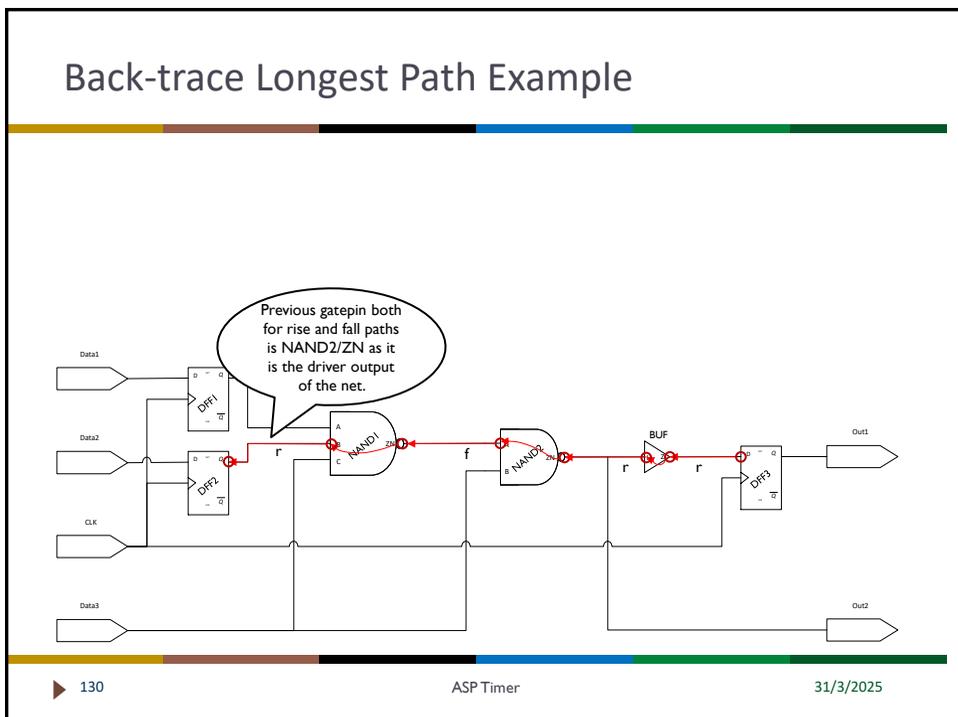
127



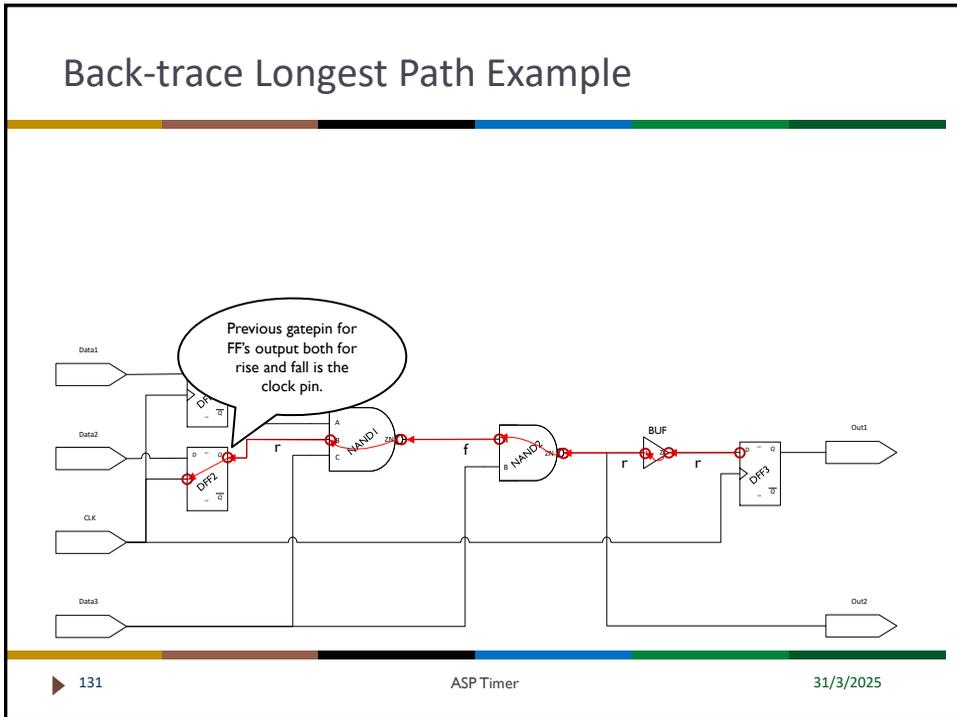
128



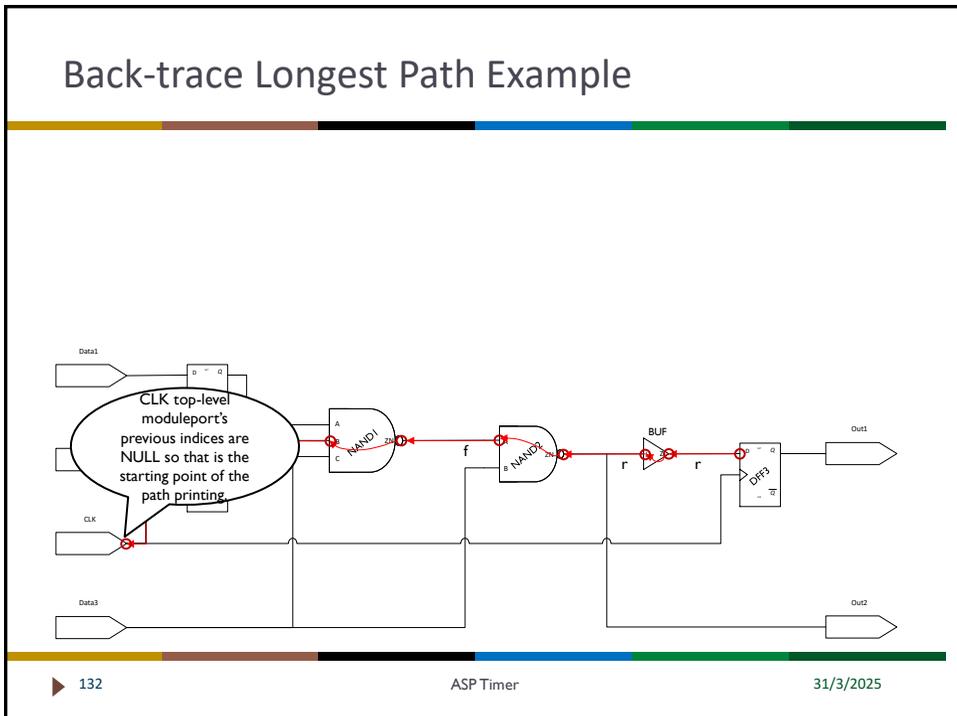
129



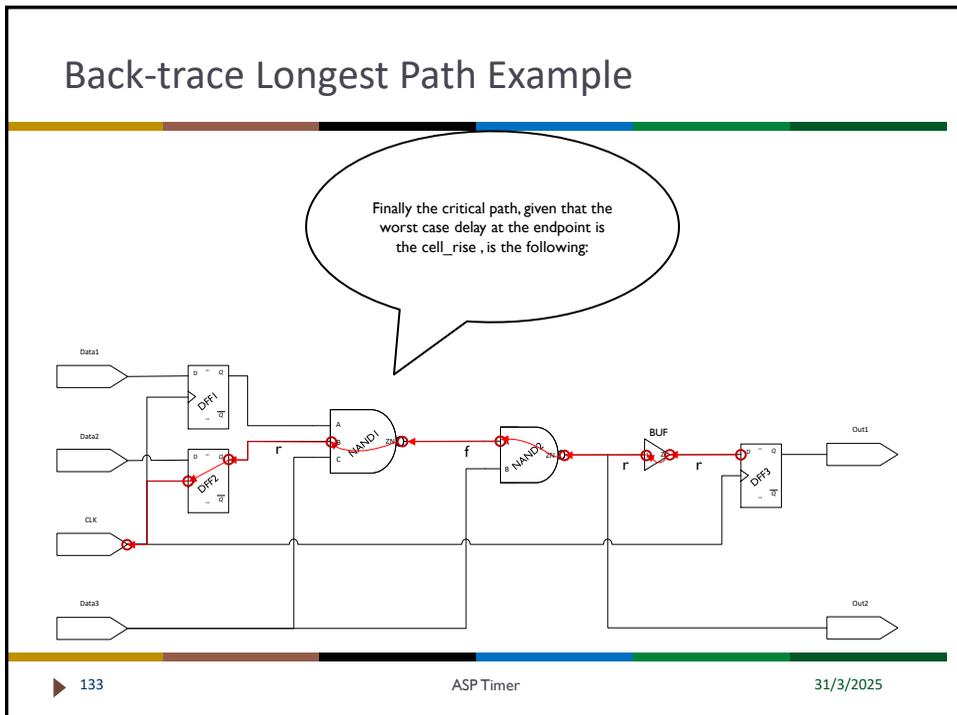
130



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Shortest Path Analysis

- ▶ The above practices can be applied for best case analysis too.
- ▶ The difference is that we get instead of max delay and transition values, the min ones.
- ▶ Also, in terms of levelisation we store the level in the first occurrence of a gatepin instead of the last one (classic BFS).
- ▶ In RAT propagation we keep the max value instead of min.
- ▶ RAT on endpoints is the hold time of the Flip-Flop. (Contrary to longest path RAT which is clock period – setup time)

▶ 134 ASP Timer 31/3/2025

134

References

- ▶ **Timing Arcs and Unateness:**
 - ▶ <http://www.vlsi-expert.com>
 - ▶ <http://vlsiuniverse.blogspot.com>
- ▶ **Simulation**
 - ▶ <https://www.swarthmore.edu/NatSci/echeeve1/Ref/mna/MNA2.html>