

Early Output Logic using Anti-Tokens

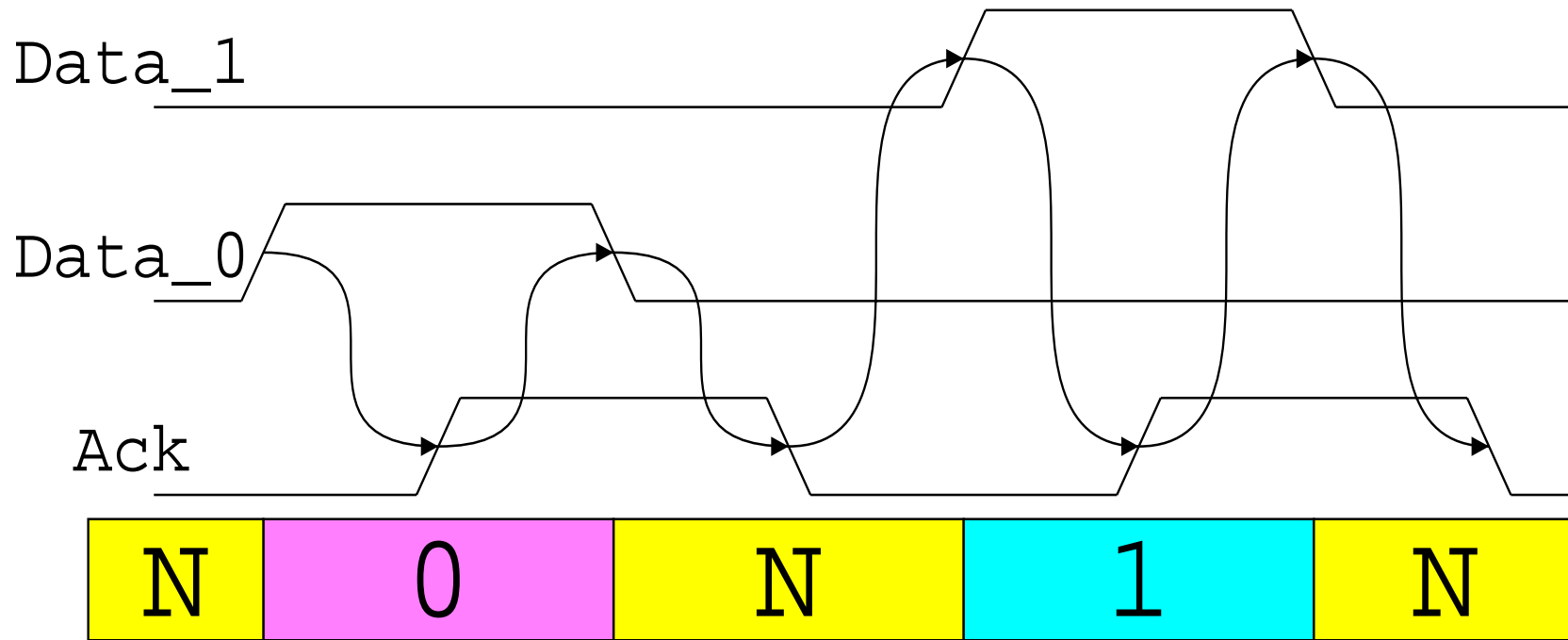
Charlie Brej
cb@cs.man.ac.uk

Amulet Group
Manchester University

Note: This talk > next talk

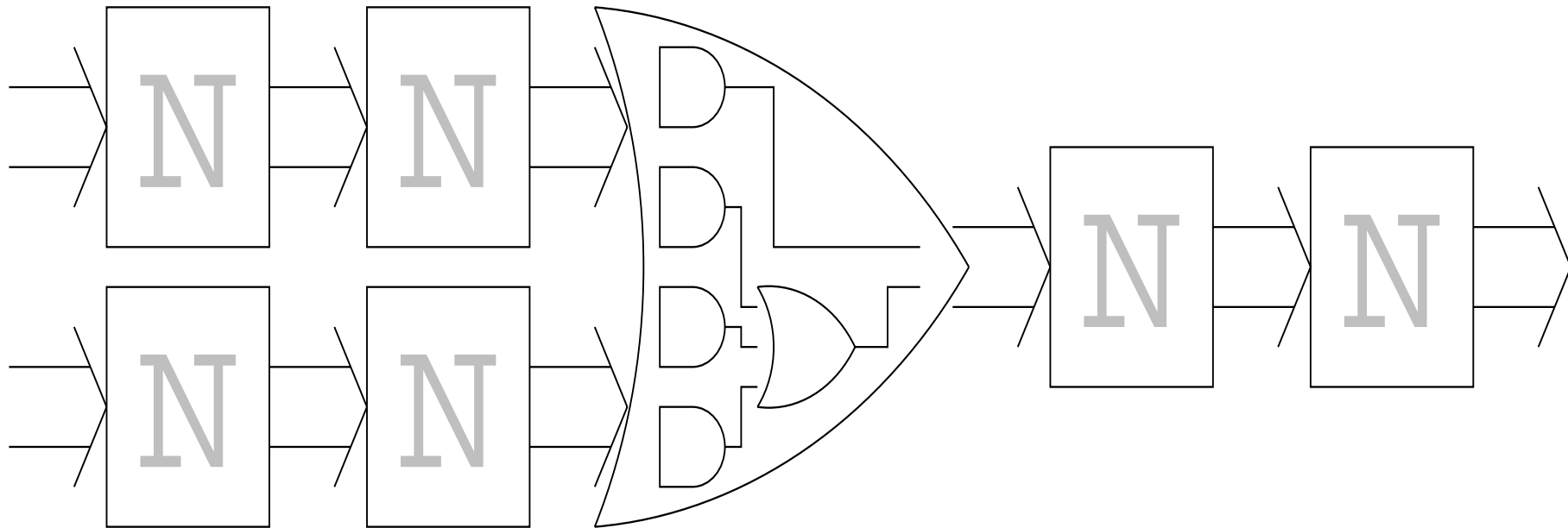


Early Output Logic using Anti-Tokens



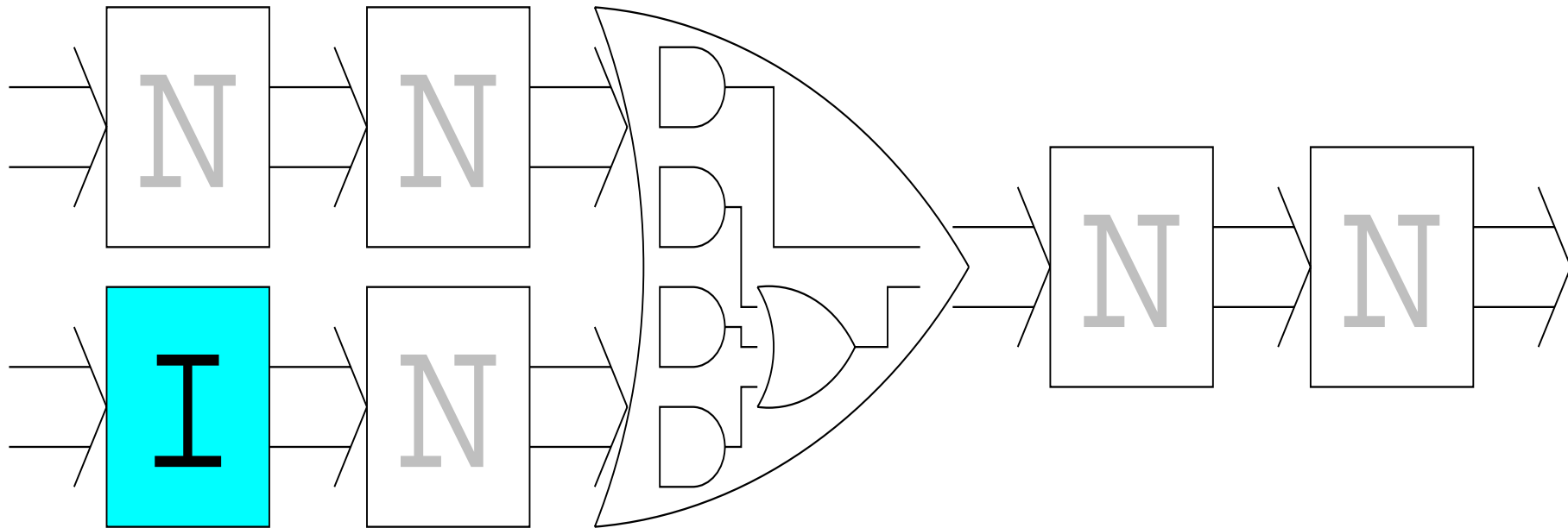
Dual-rail, four-phase, return to zero, protocol

Early Output Logic using Anti-Tokens

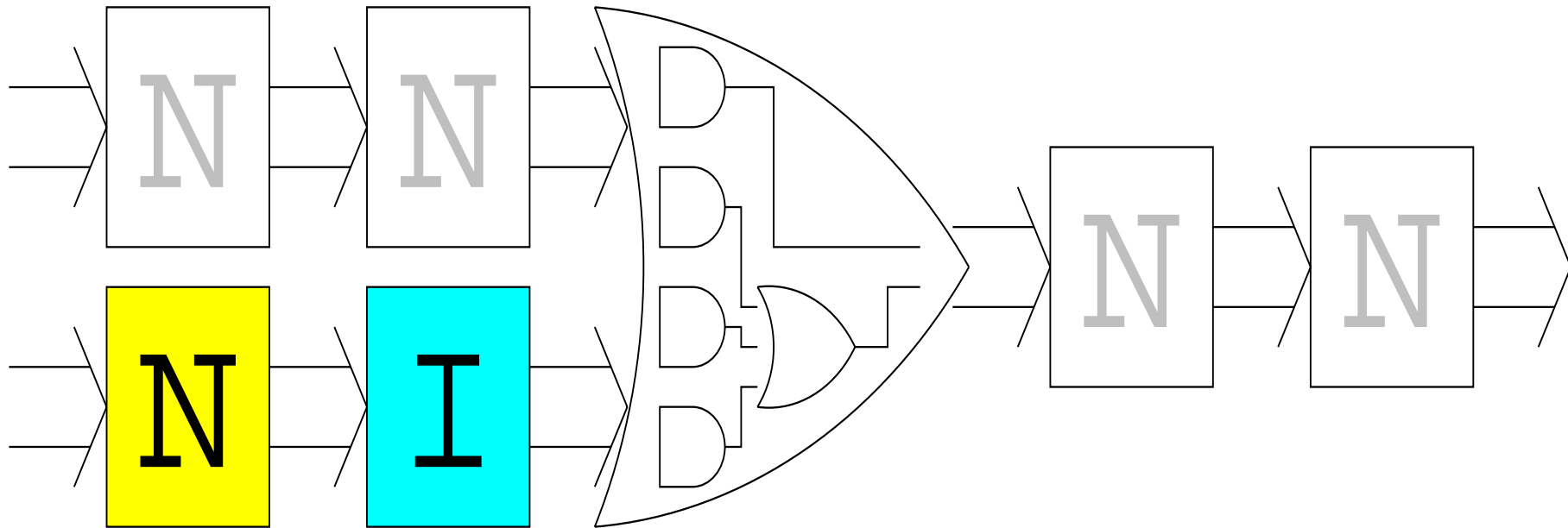


DIMS OR gate example

Early Output Logic using Anti-Tokens

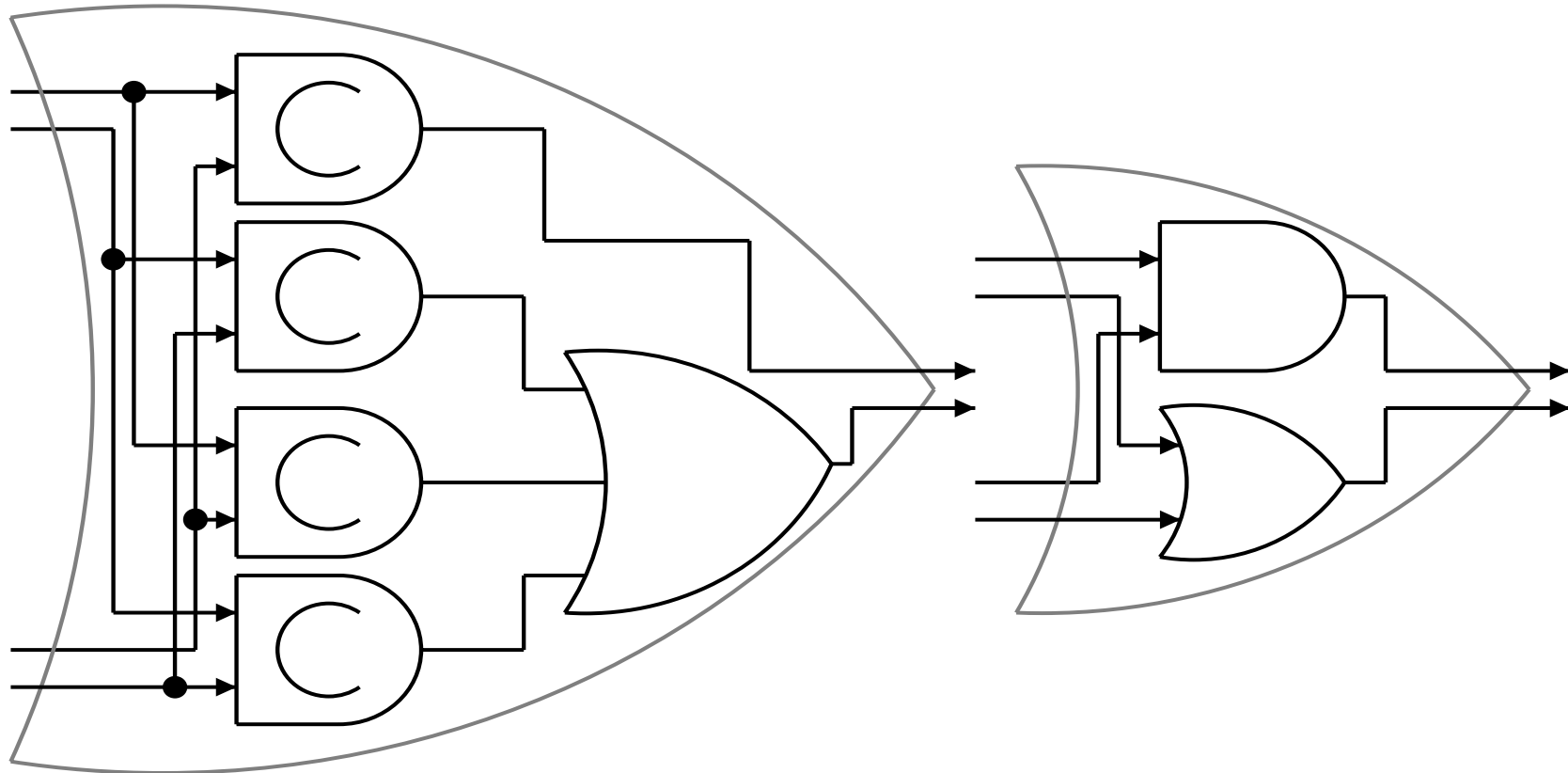


Early Output Logic using Anti-Tokens



Gate stuck in set phase

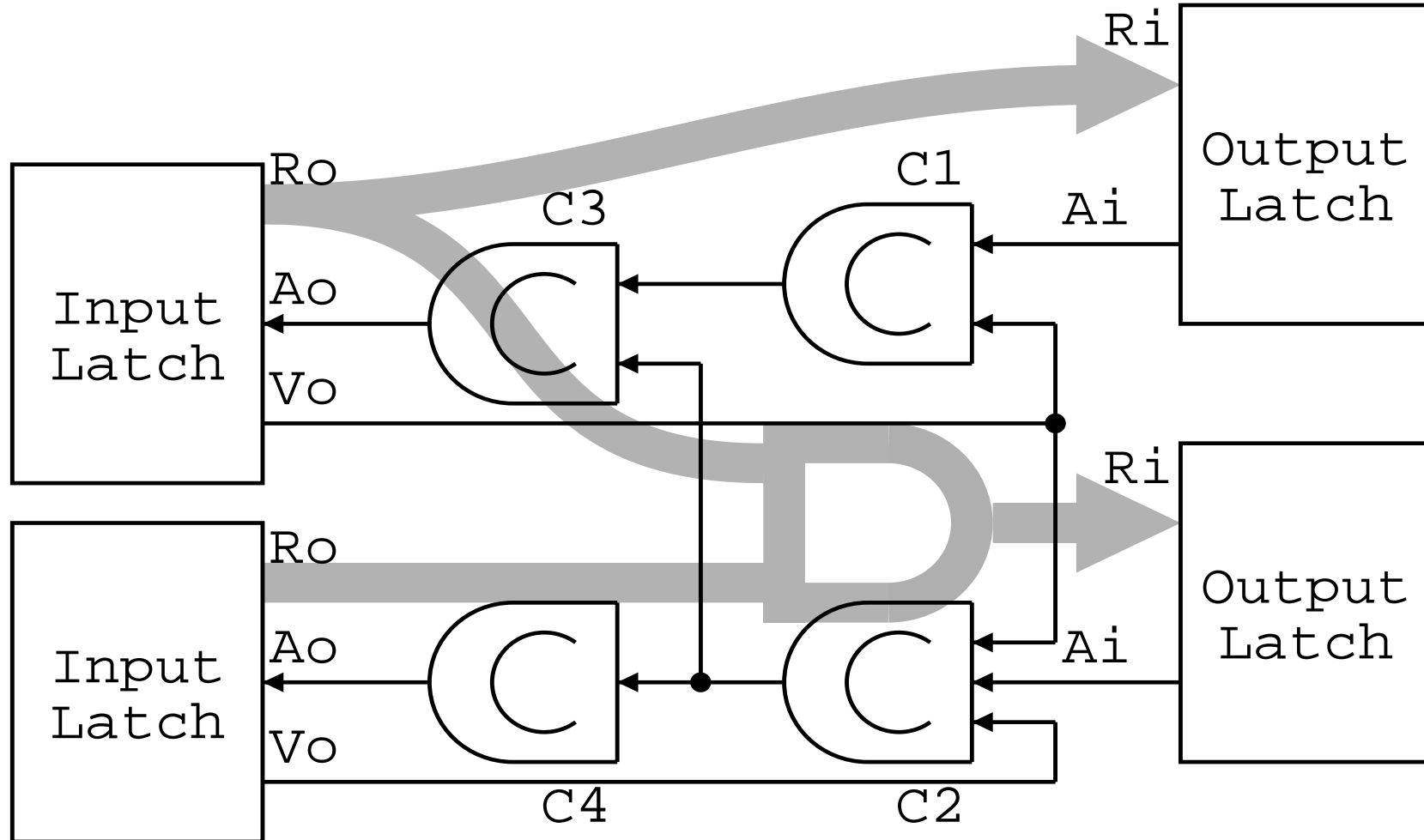
Early Output Logic using Anti-Tokens



	0	N	1
0	0	N	1
N	N	N	N
1	1	N	1

	0	N	1
0	0	N	1
N	N	N	1*
1	1	1*	1

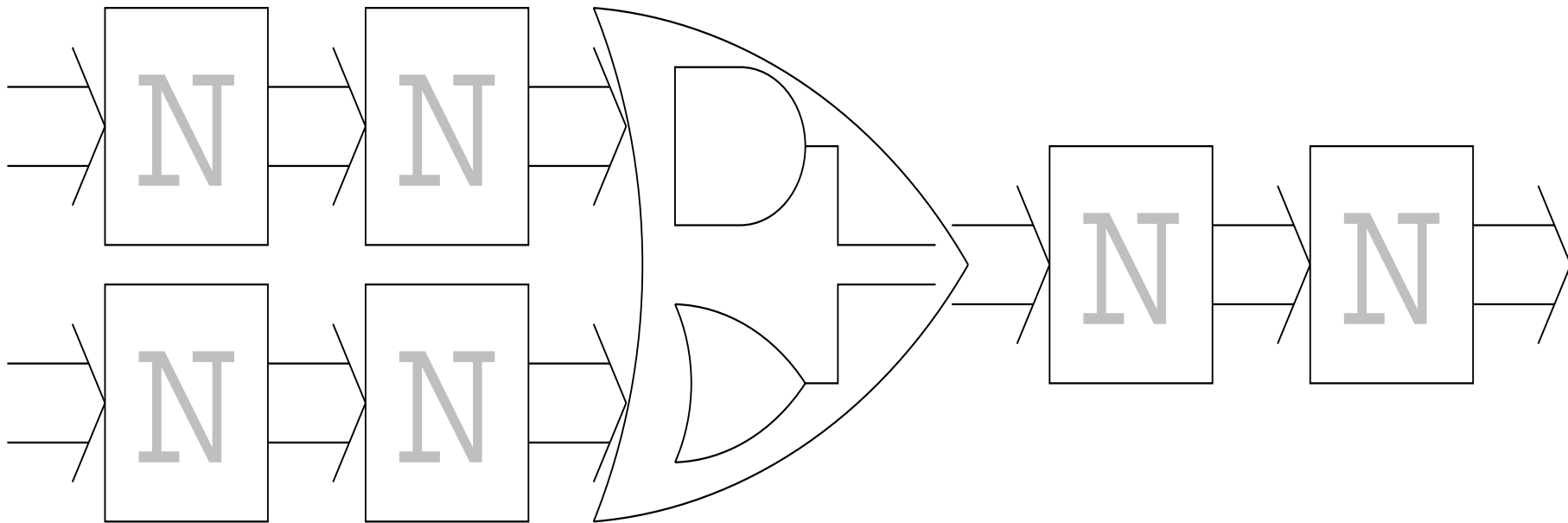
Early Output Logic using Anti-Tokens



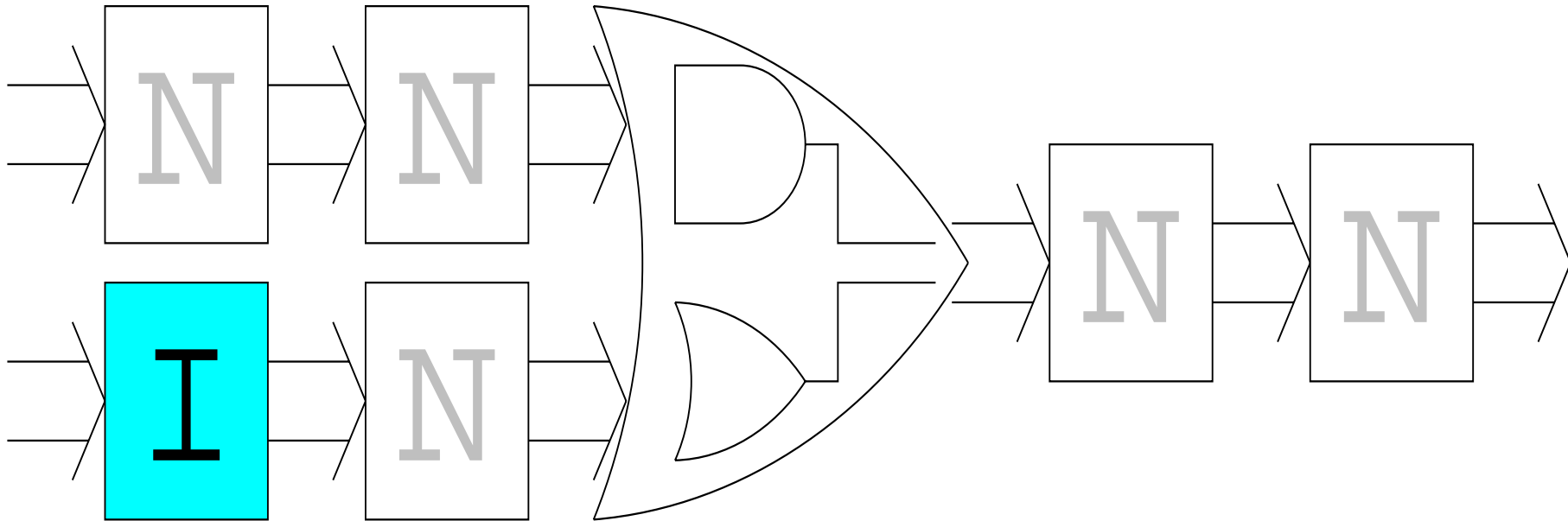
Guarding example



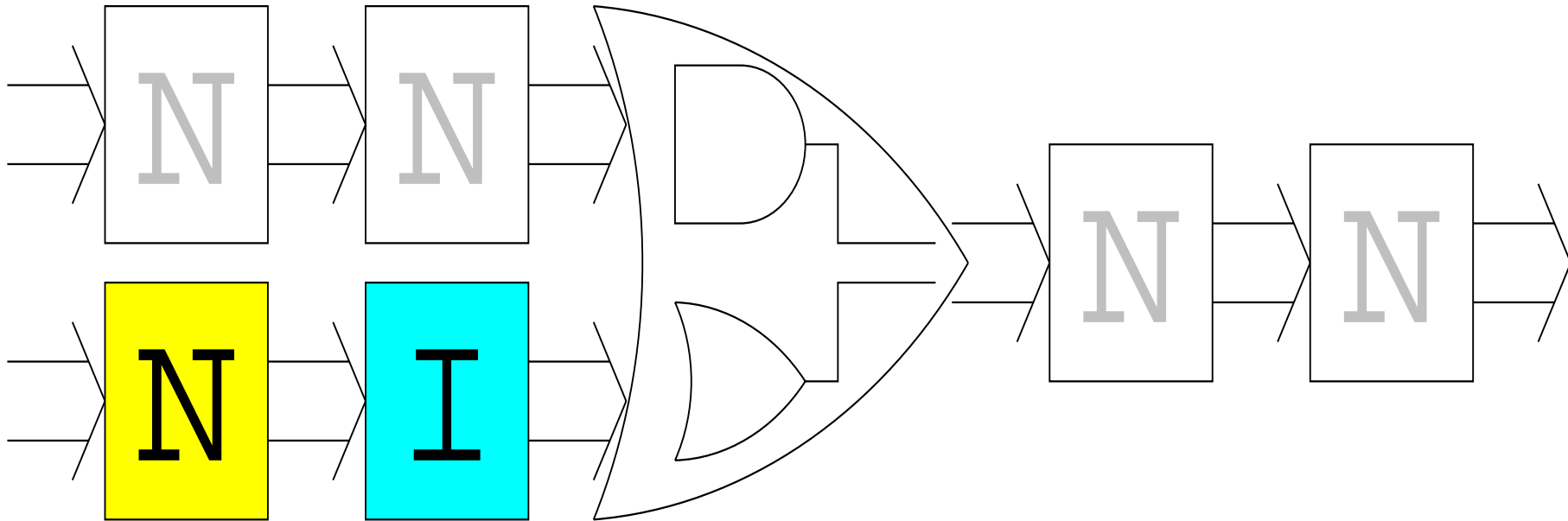
Early Output Logic using Anti-Tokens



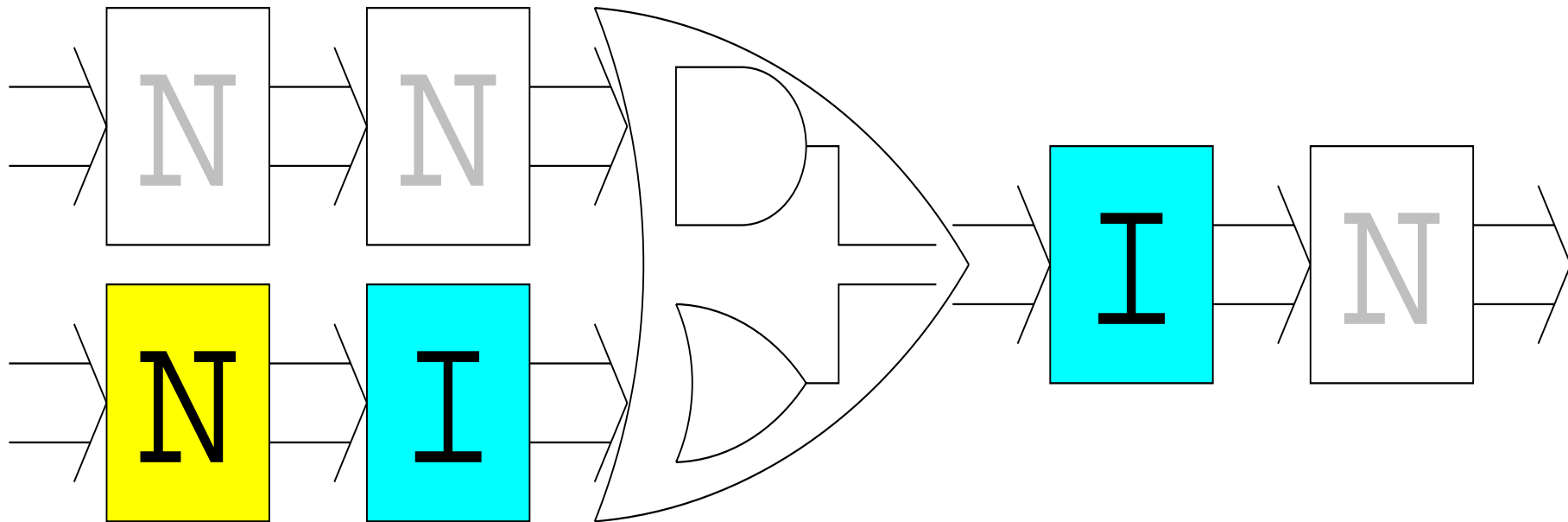
Early Output Logic using Anti-Tokens



Early Output Logic using Anti-Tokens

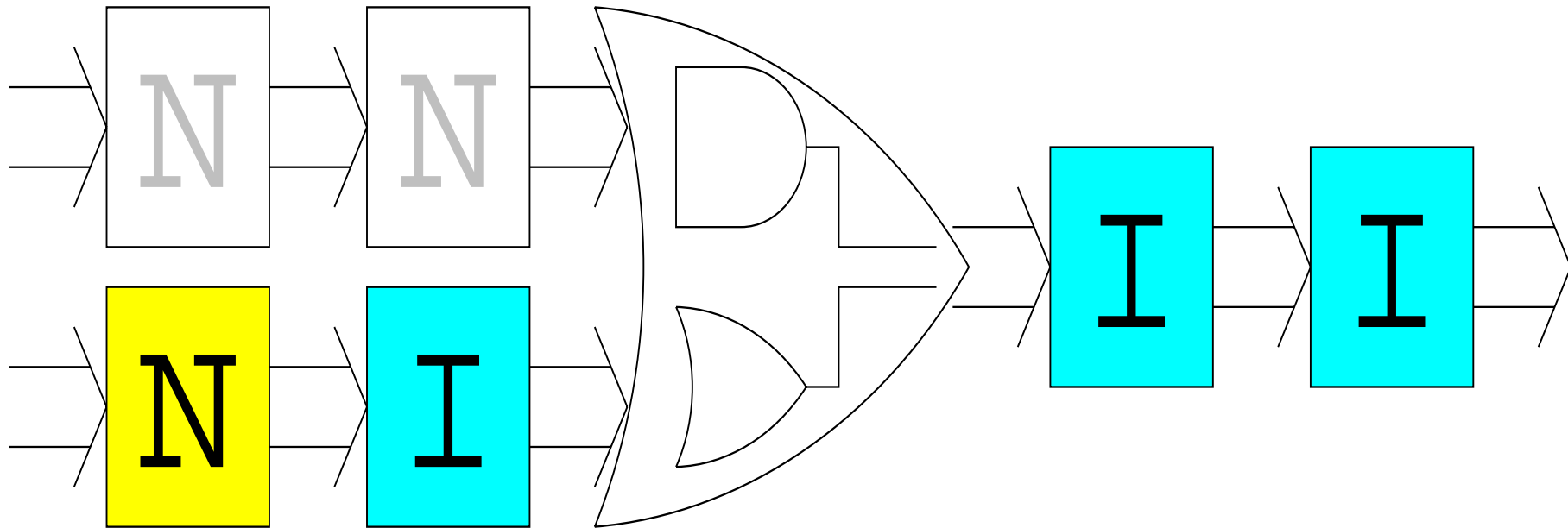


Early Output Logic using Anti-Tokens



Data is sufficient to create a result
Early output case

Early Output Logic using Anti-Tokens



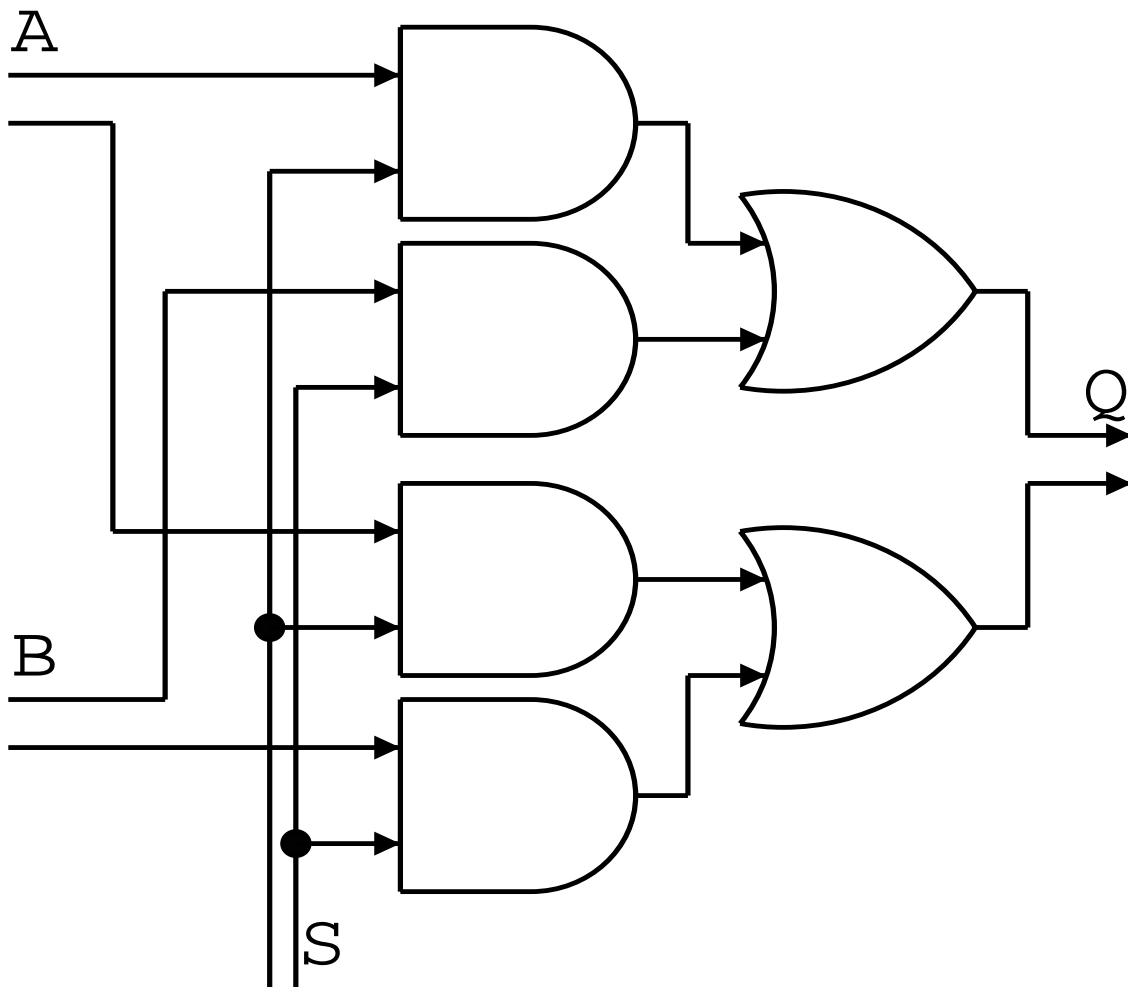
Early output case

Safe

No acknowledgement until other input arrives

More early output cases

Early Output Logic using Anti-Tokens

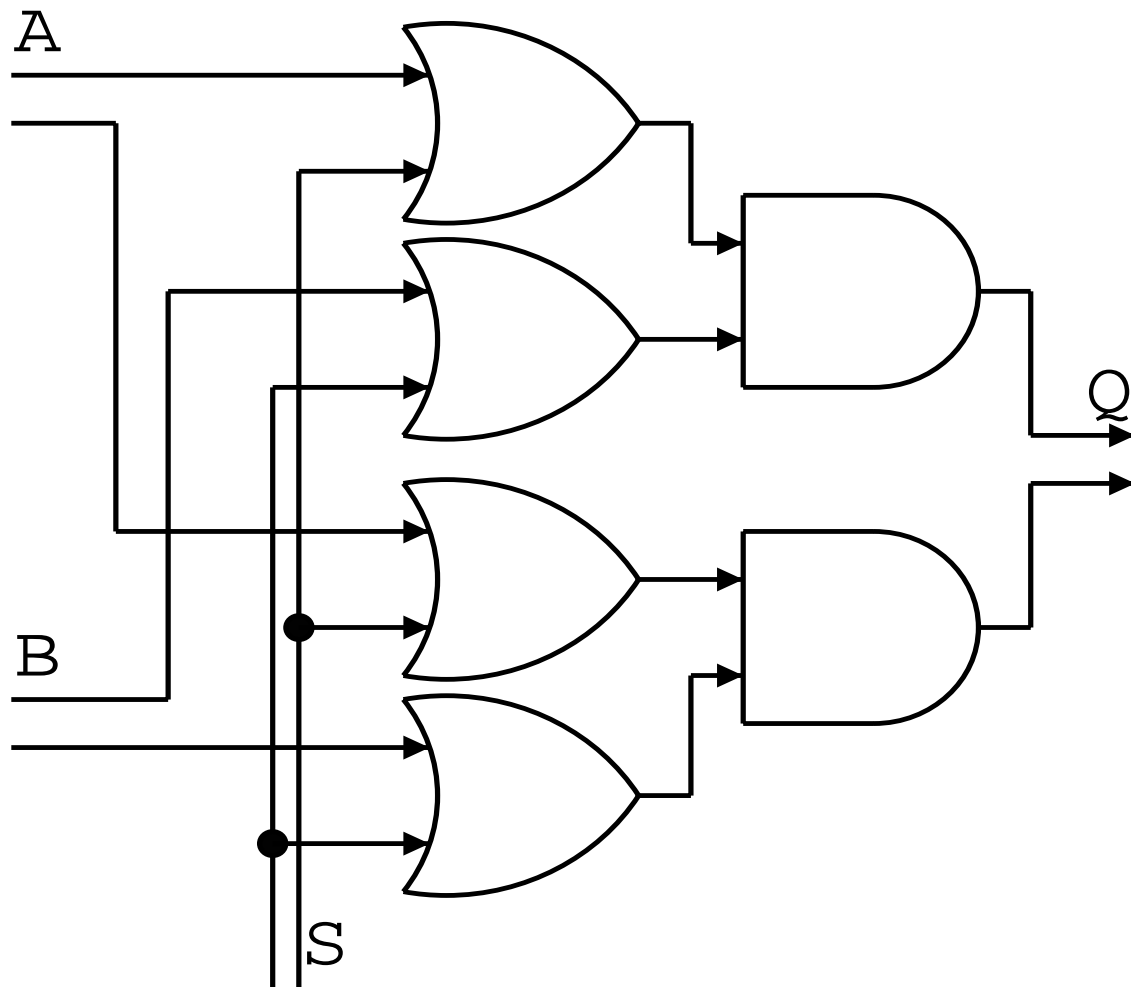


		S		
A	B	N	0	1
N	N	N	N	N
0	N	N	0*	N
1	N	N	1*	N
N	0	N	N	0*
0	0	N	0	0
1	0	N	1	0
N	1	N	N	1*
0	1	N	0	1
1	1	N	1	1

2:1 multiplexer design



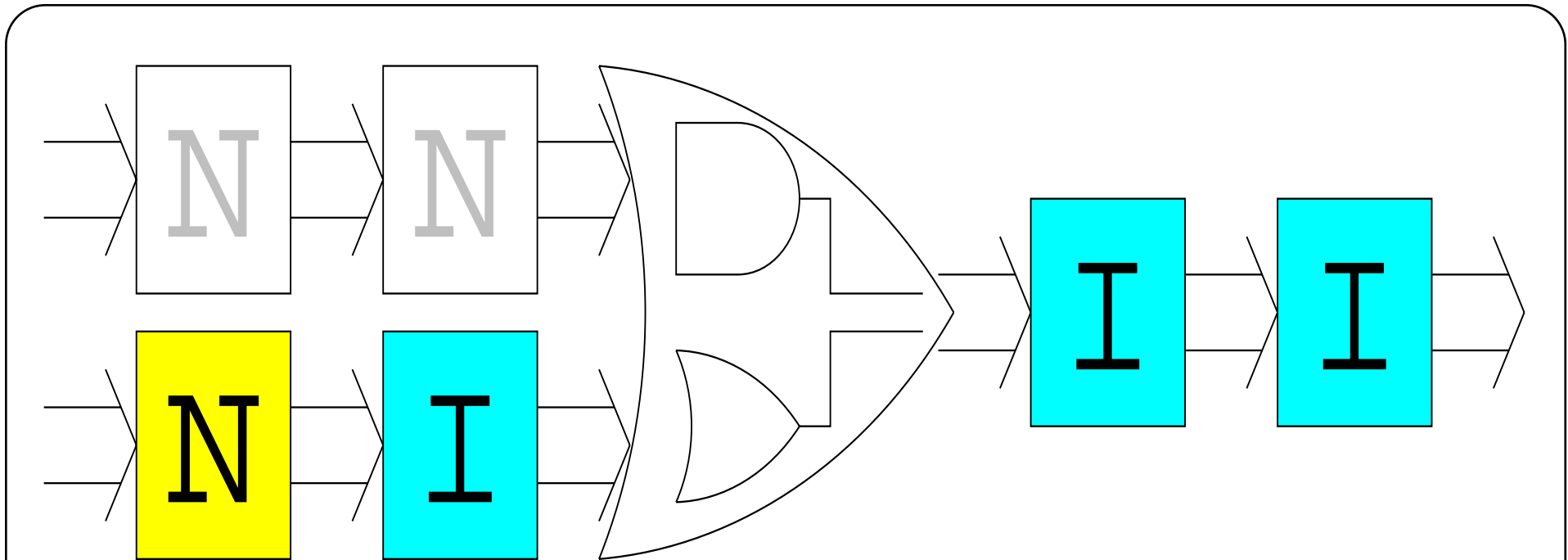
Early Output Logic using Anti-Tokens



		S		
A	B	N	0	1
N	N	N	N	N
0	N	N	0*	N
1	N	N	1*	N
N	0	N	N	0*
0	0	0*	0	0
1	0	N	1	0
N	1	N	N	1*
0	1	N	0	1
1	1	1*	1	1

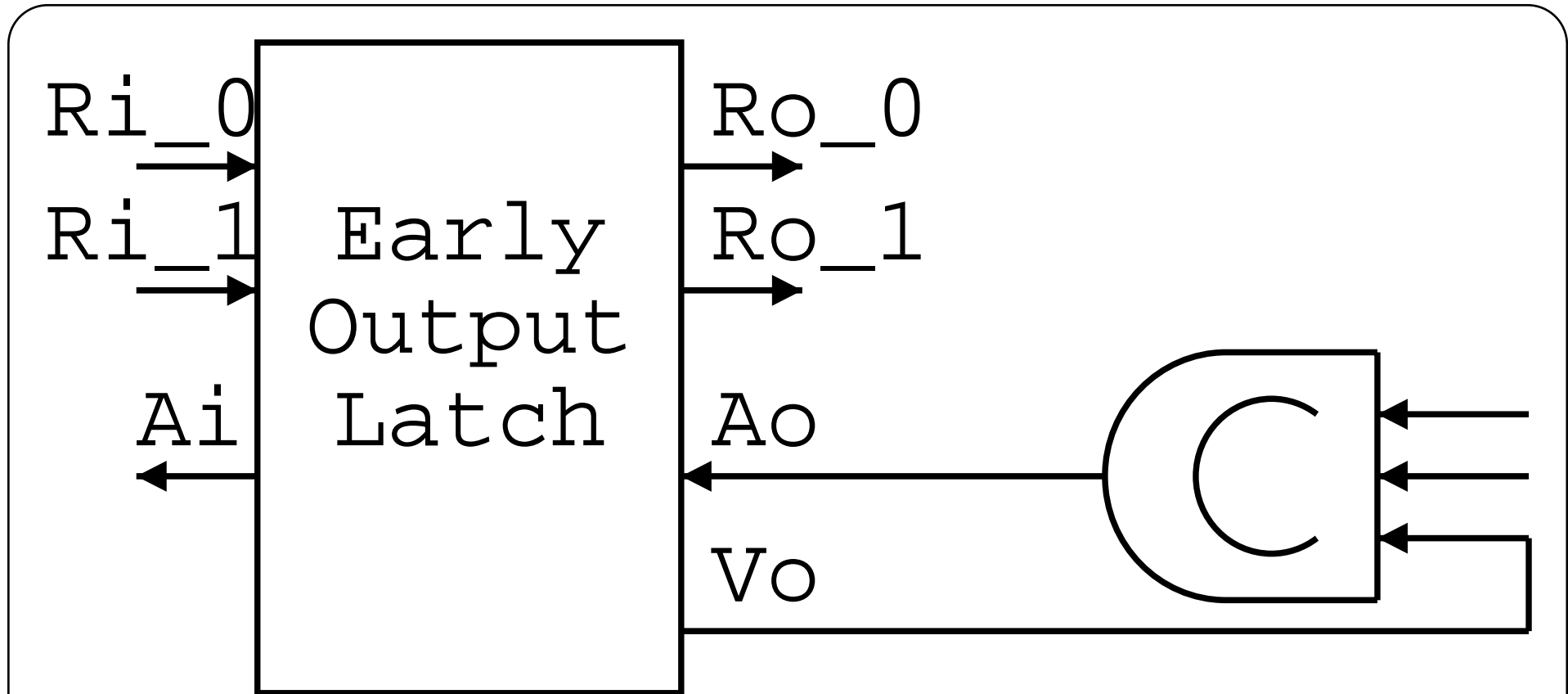
Alternative 2:1 multiplexer design
Two more early output cases

Early Output Logic using Anti-Tokens



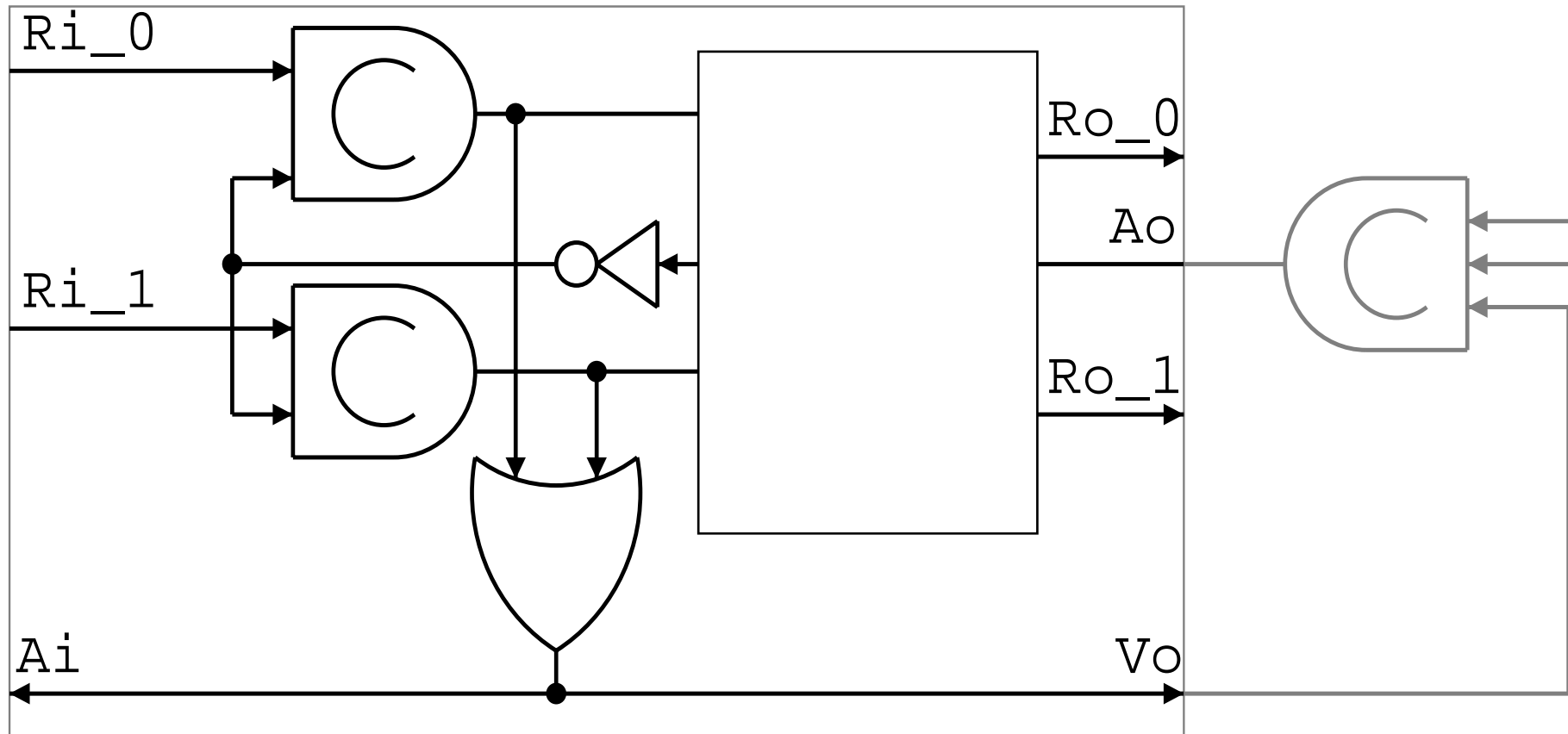
Stuck in data phase
Semi-decoupled latch

Early Output Logic using Anti-Tokens



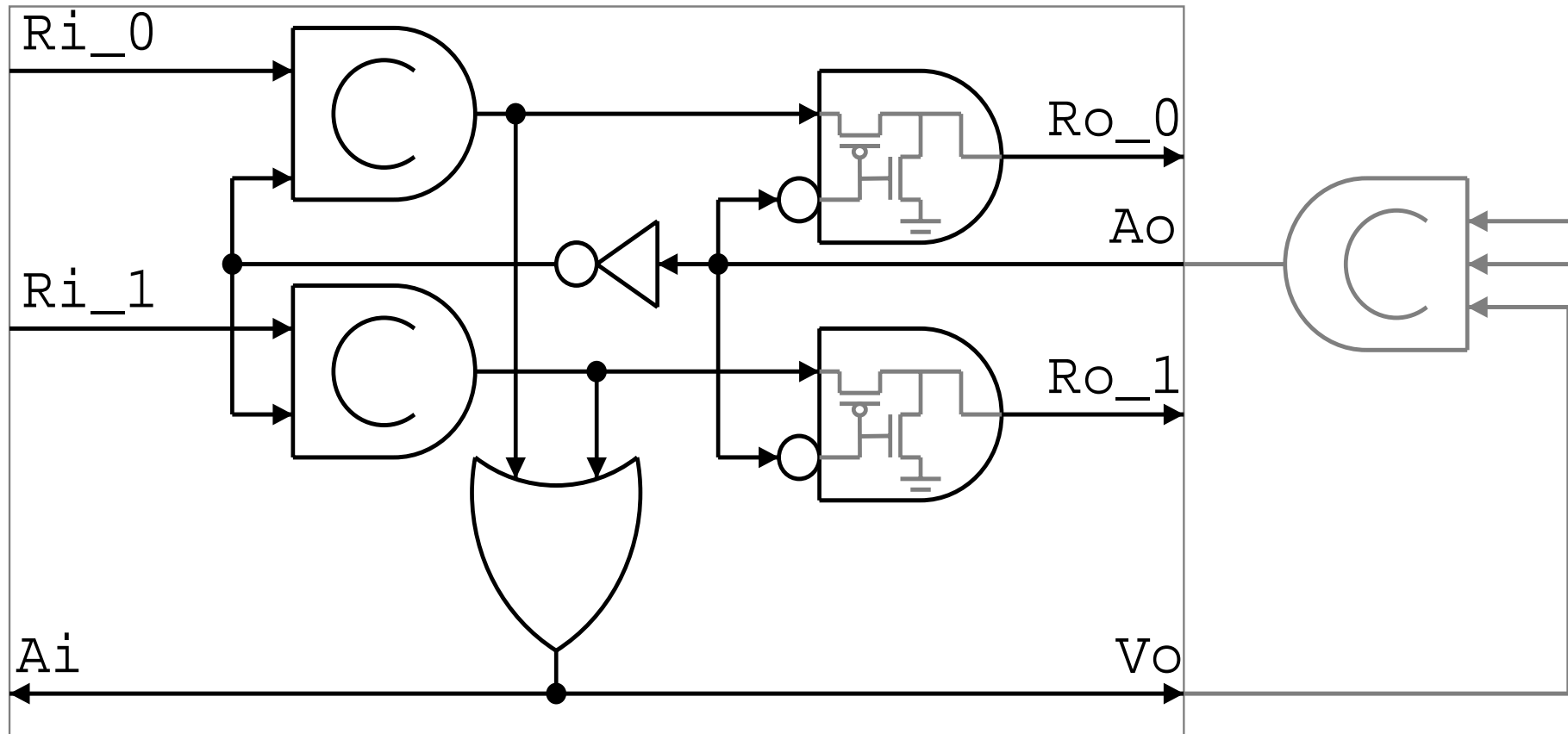
Validity to acknowledge connection

Early Output Logic using Anti-Tokens



Early output semi-decoupled latch

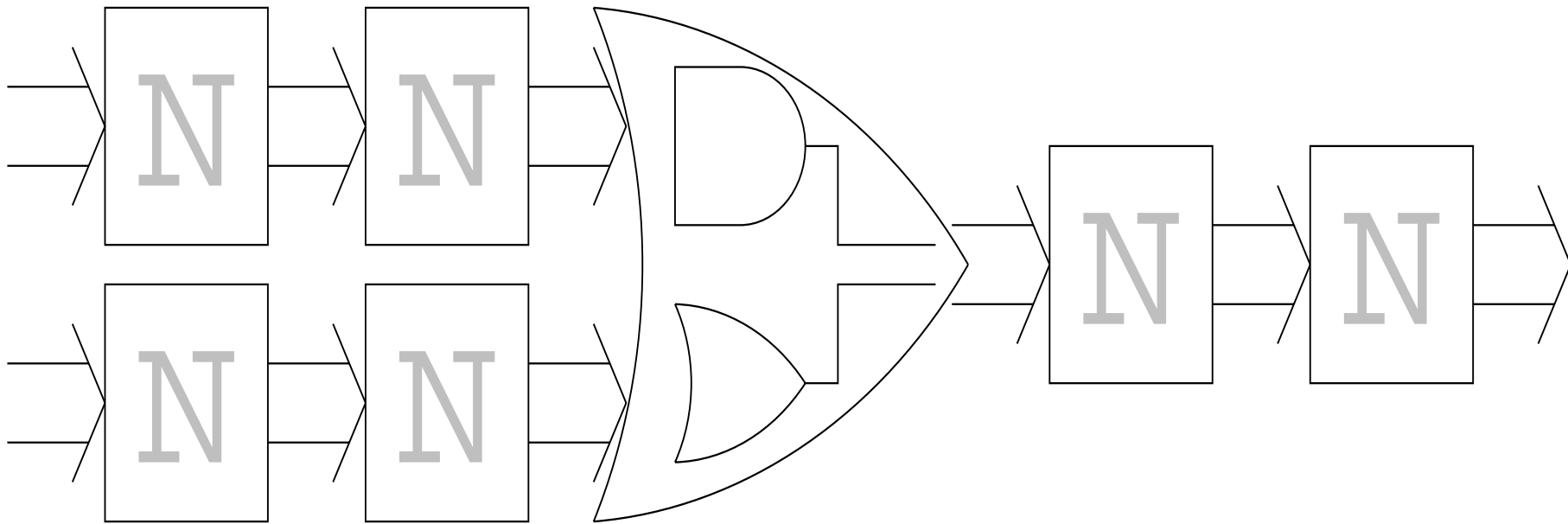
Early Output Logic using Anti-Tokens



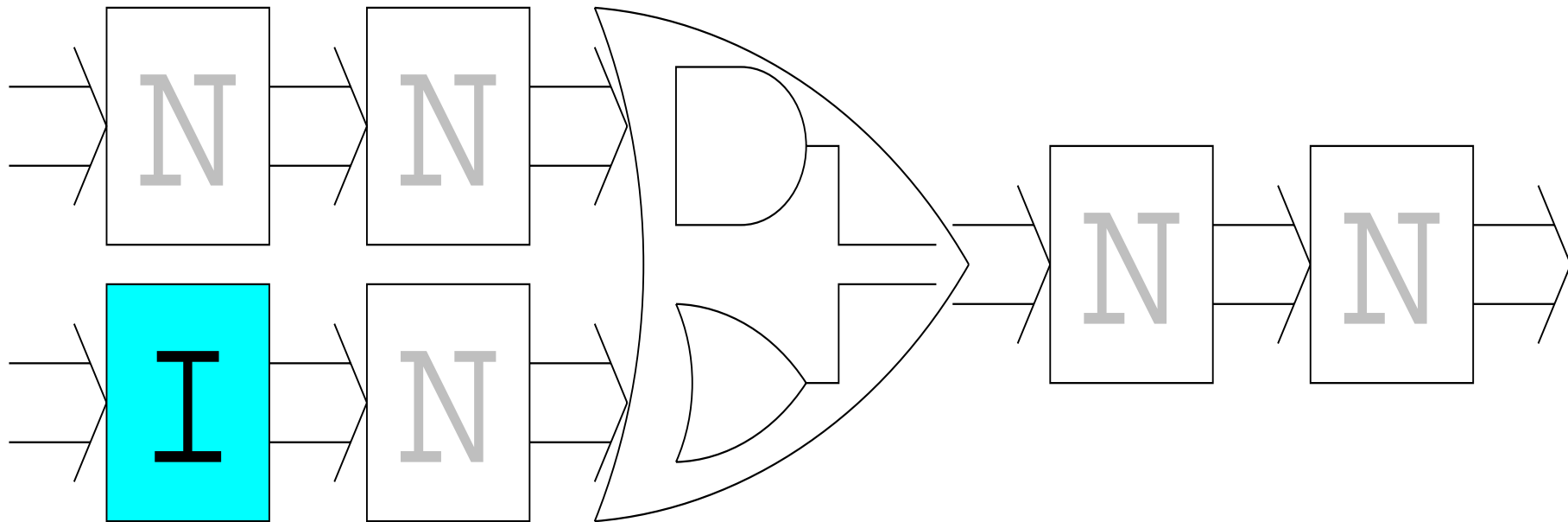
Early output semi-decoupled latch



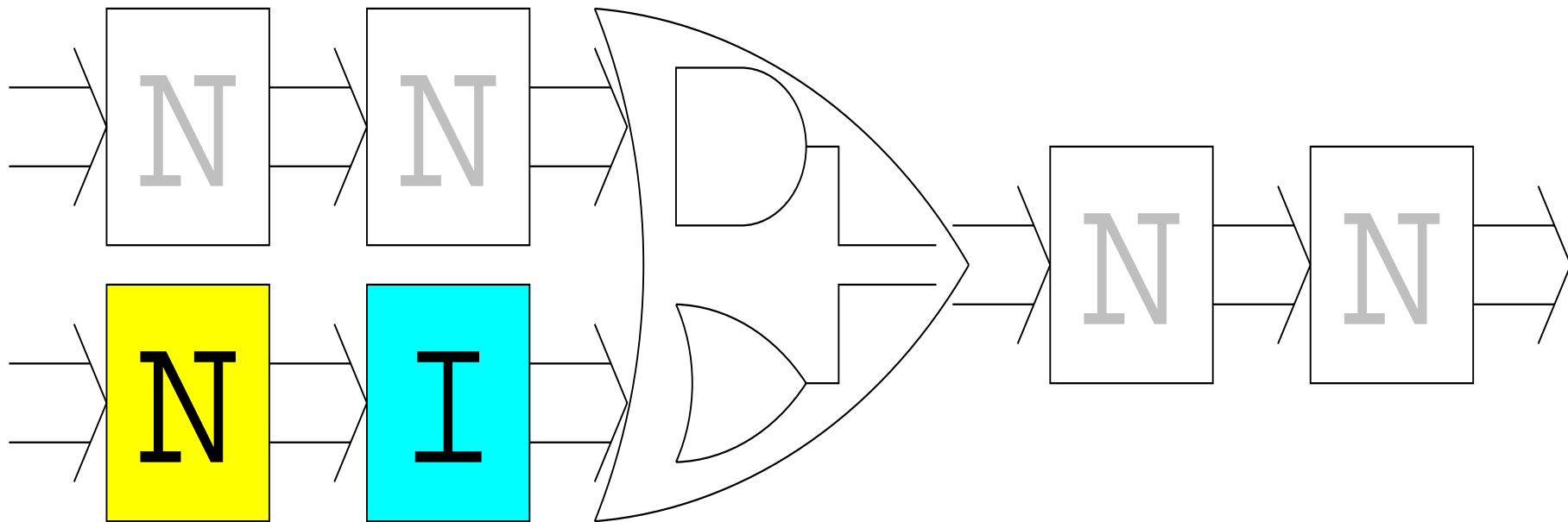
Early Output Logic using Anti-Tokens



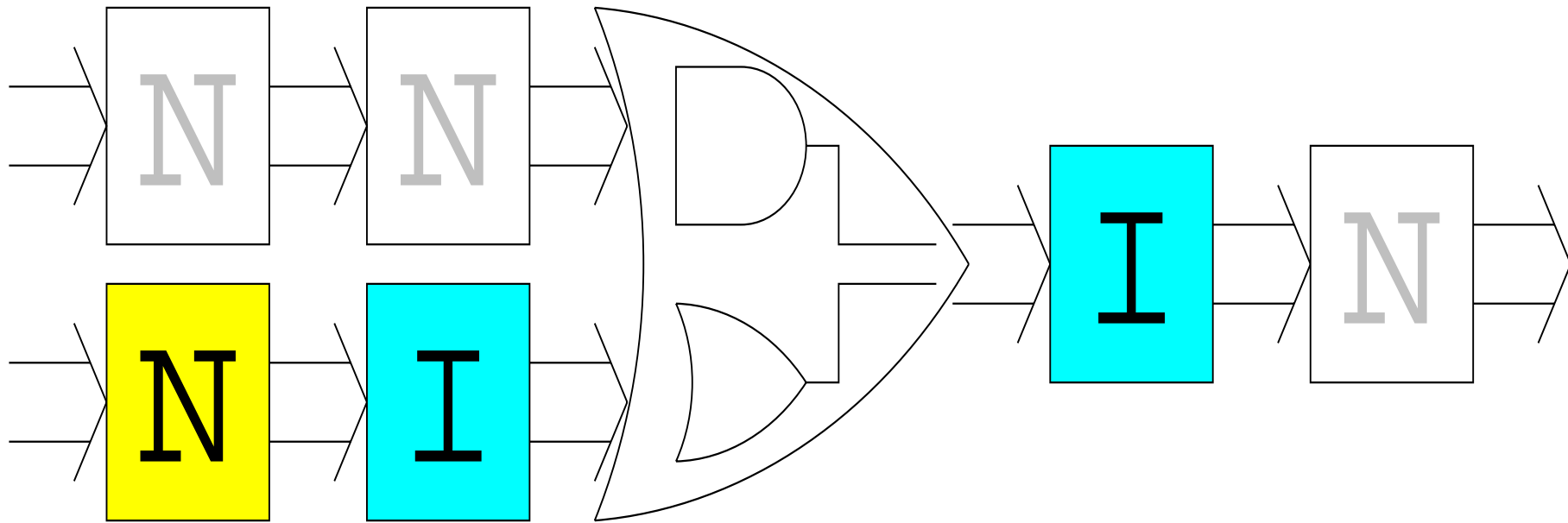
Early Output Logic using Anti-Tokens



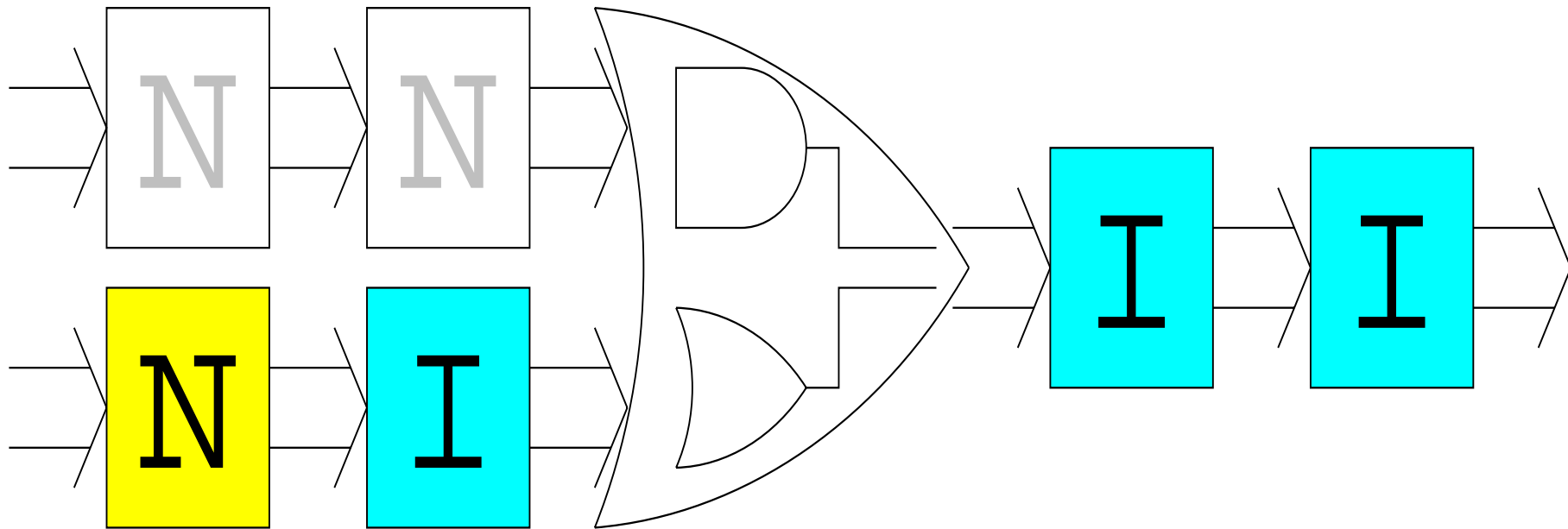
Early Output Logic using Anti-Tokens



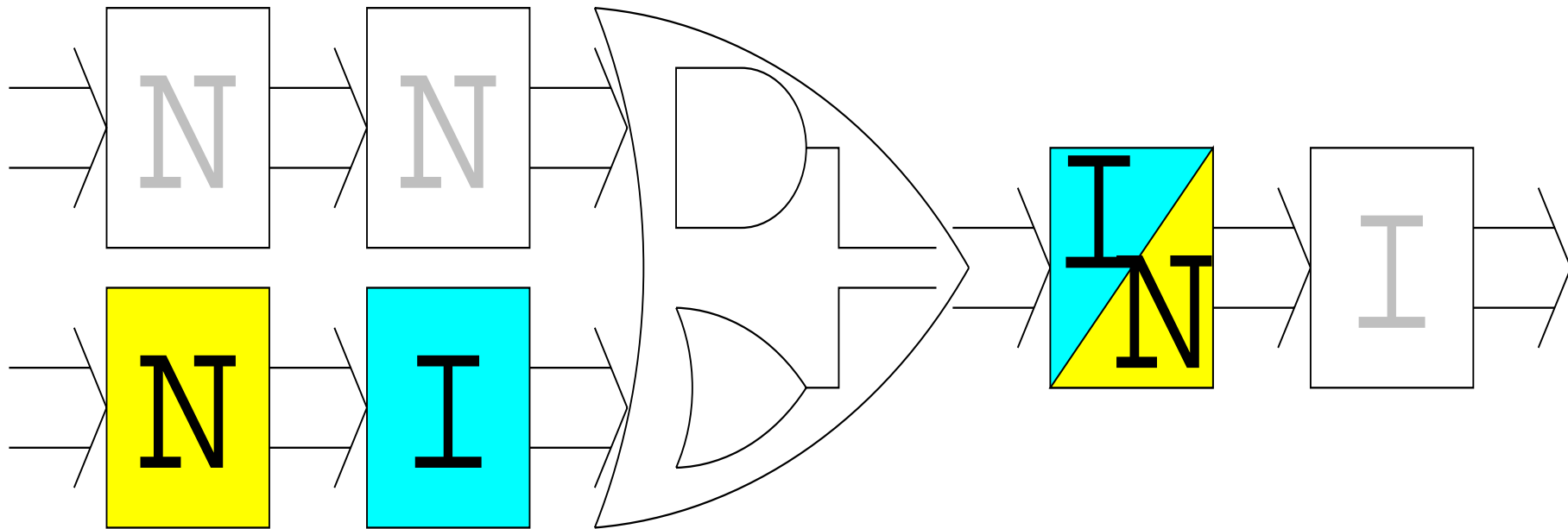
Early Output Logic using Anti-Tokens



Early Output Logic using Anti-Tokens

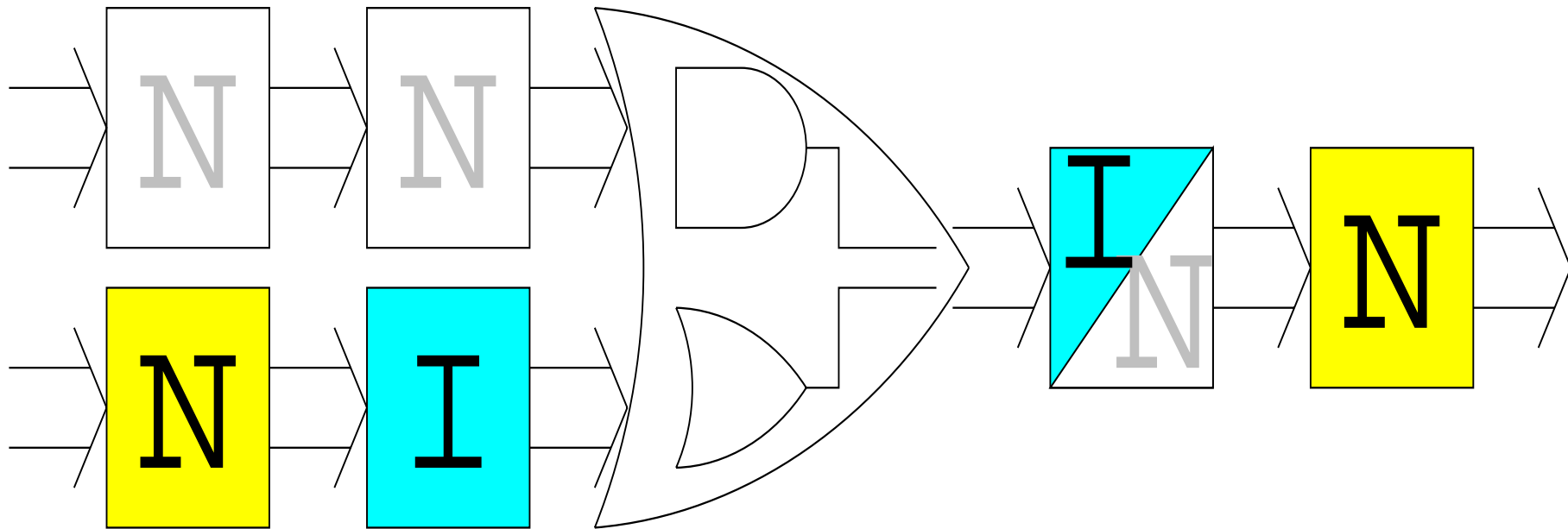


Early Output Logic using Anti-Tokens

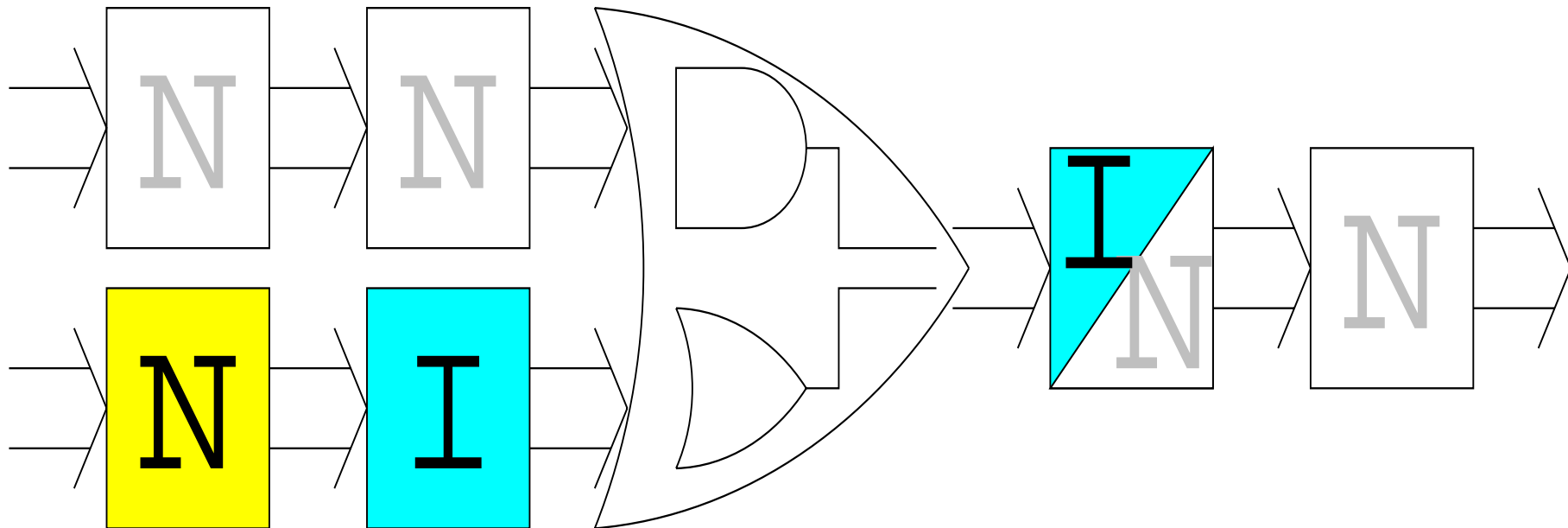


Semi-decoupled latch outputs a NULL

Early Output Logic using Anti-Tokens



Early Output Logic using Anti-Tokens



Later stages free to continue but OR gate is stuck
Tell top pipeline to throw away next token

Anti-Token Latches

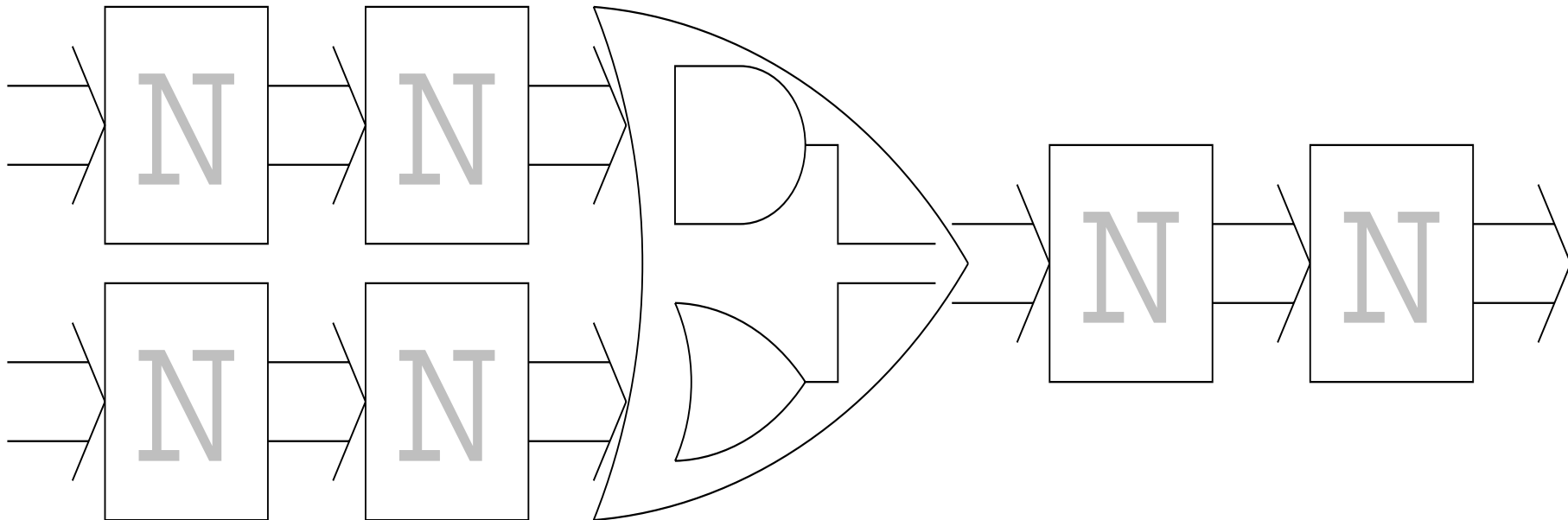
Assert validity early

Receive acknowledge early

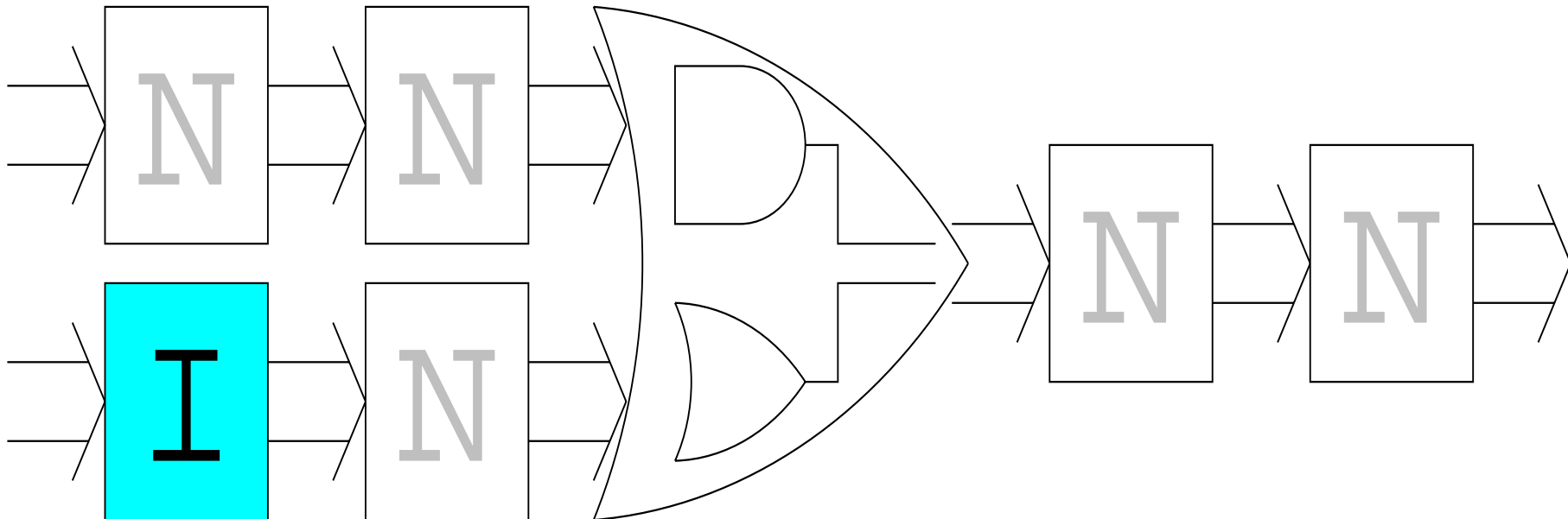
Hold an anti-token

Pass an anti-token backwards

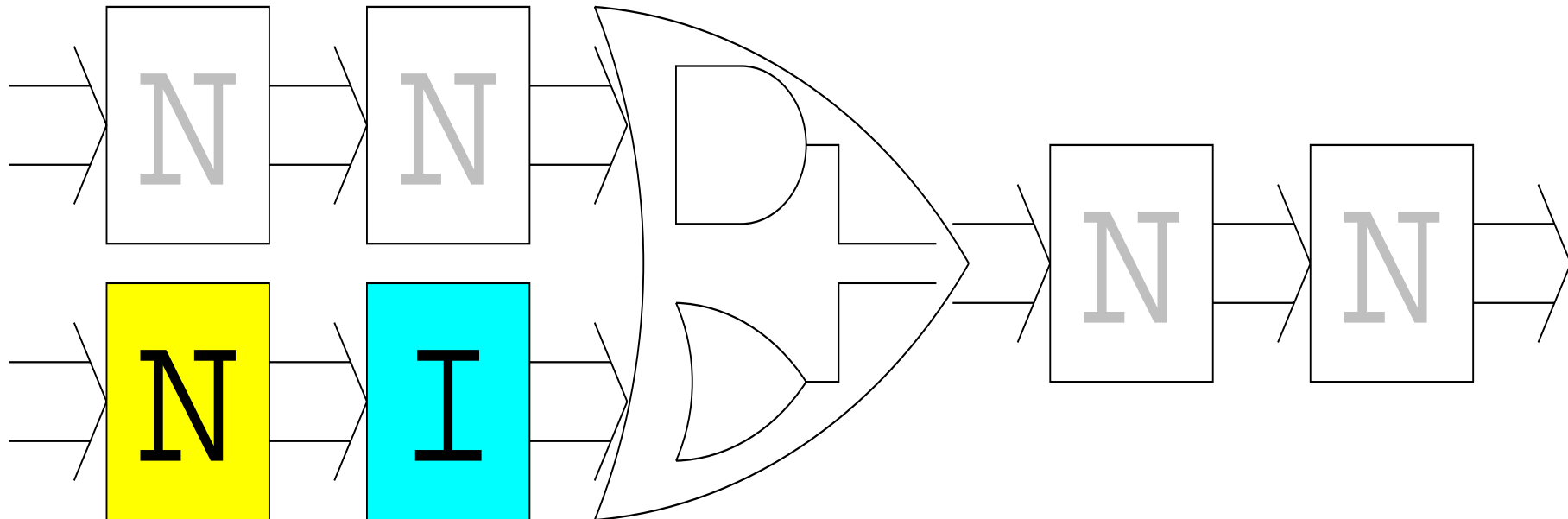
Early Output Logic using Anti-Tokens



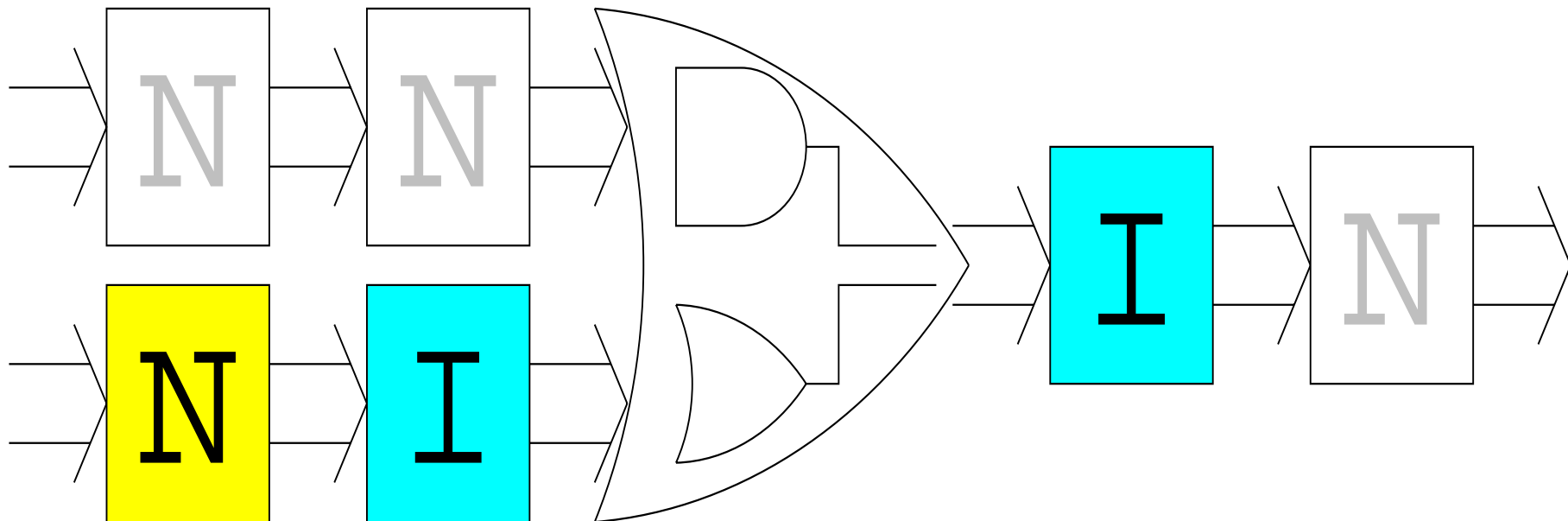
Early Output Logic using Anti-Tokens



Early Output Logic using Anti-Tokens

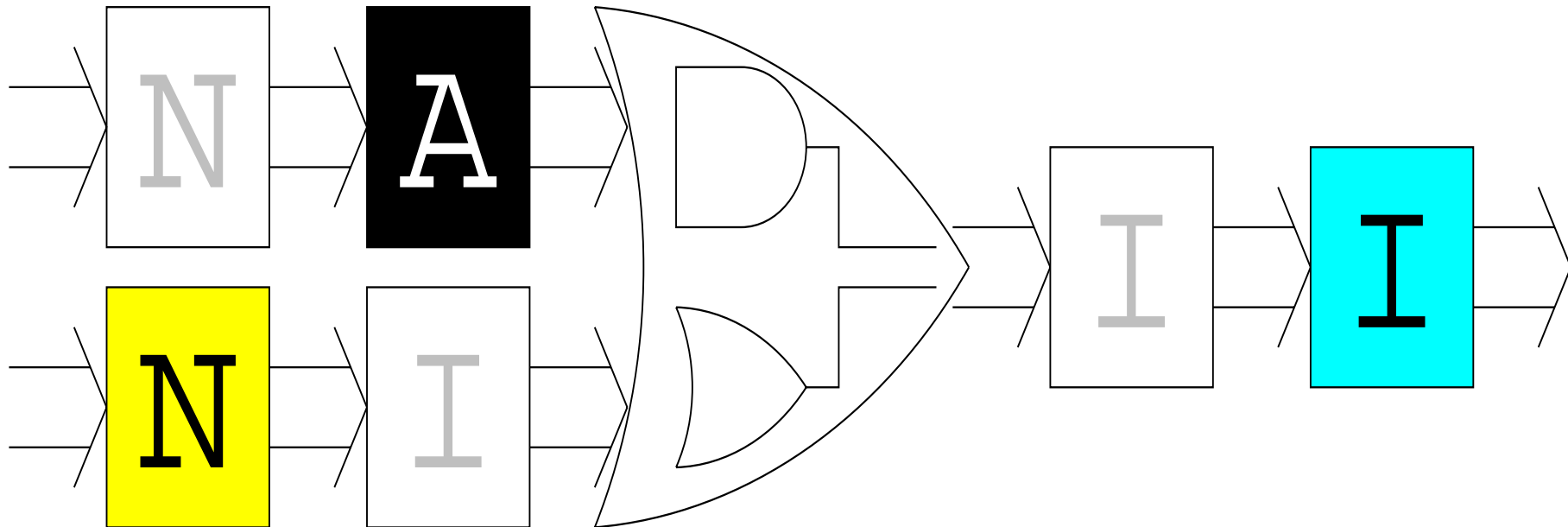


Early Output Logic using Anti-Tokens



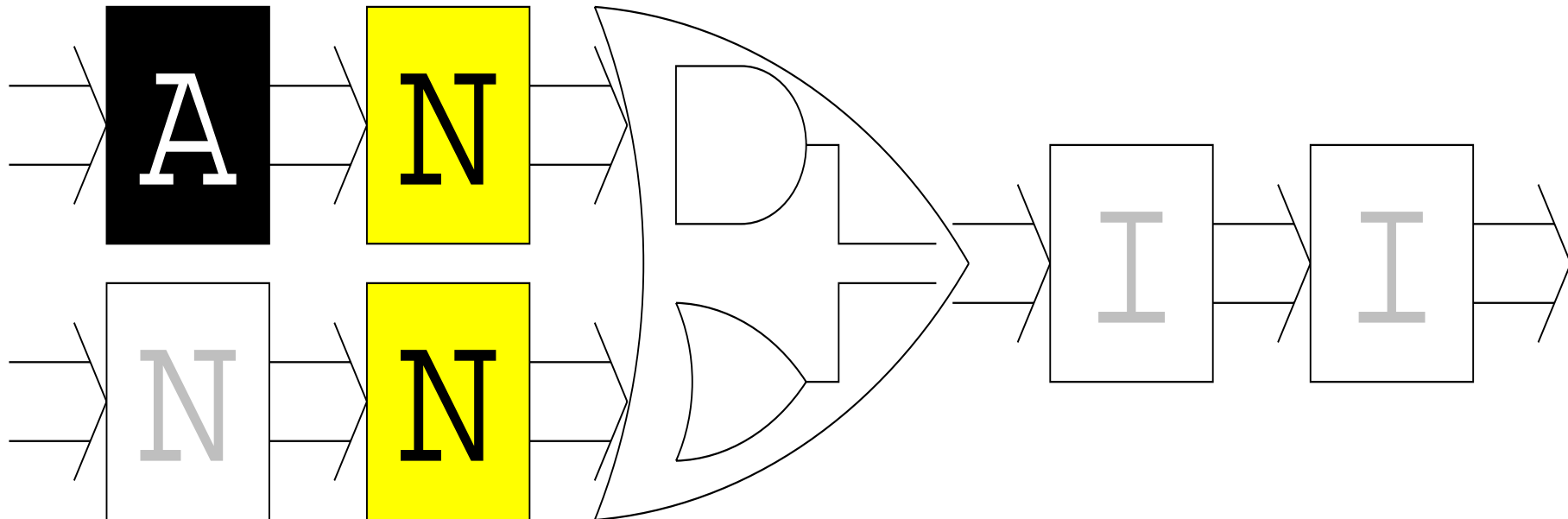
Data generated so latch acknowledges
Top latch asserts validity early

Early Output Logic using Anti-Tokens

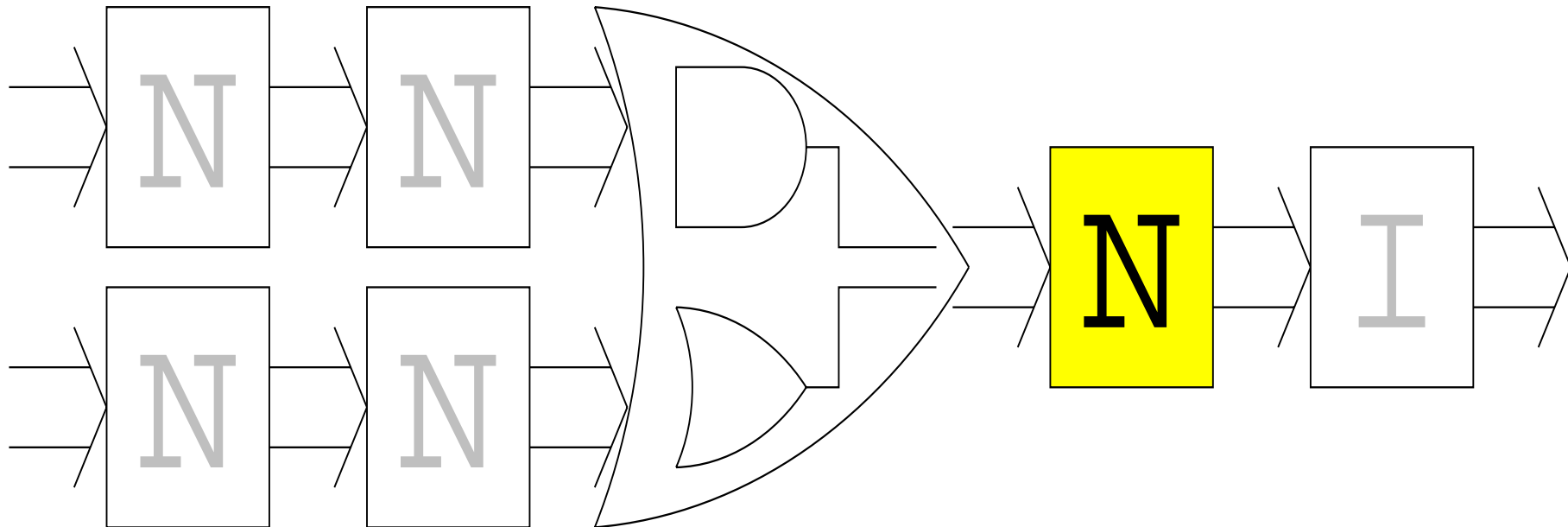


Top latch receives an anti-token

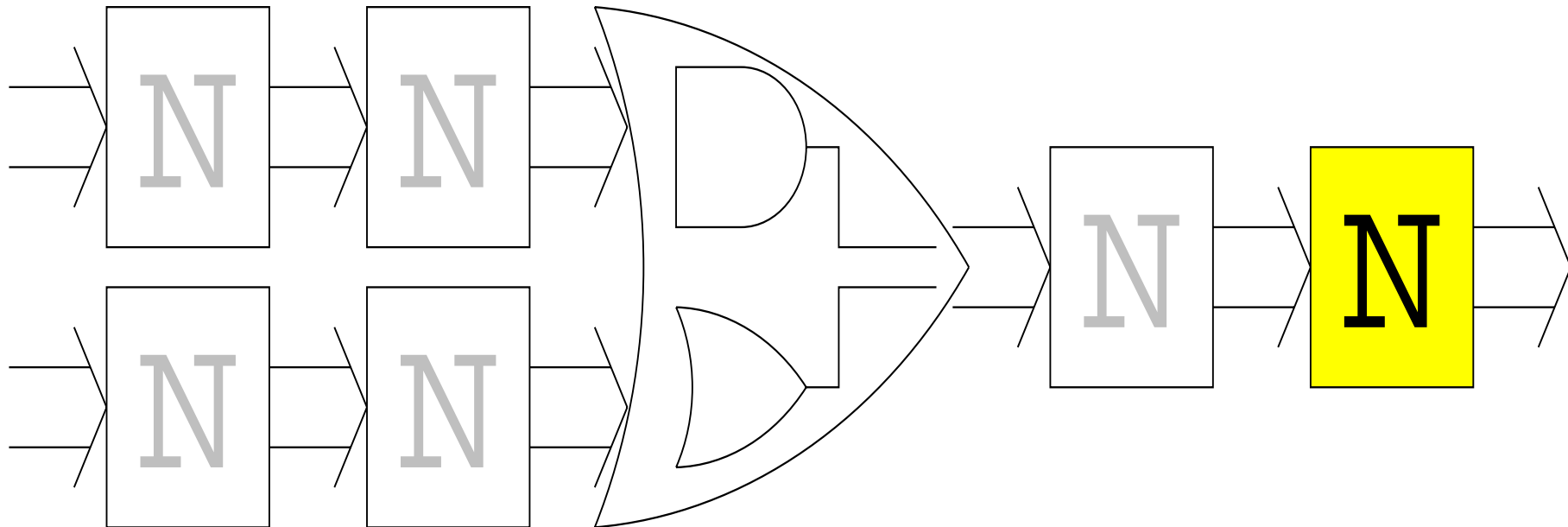
Early Output Logic using Anti-Tokens



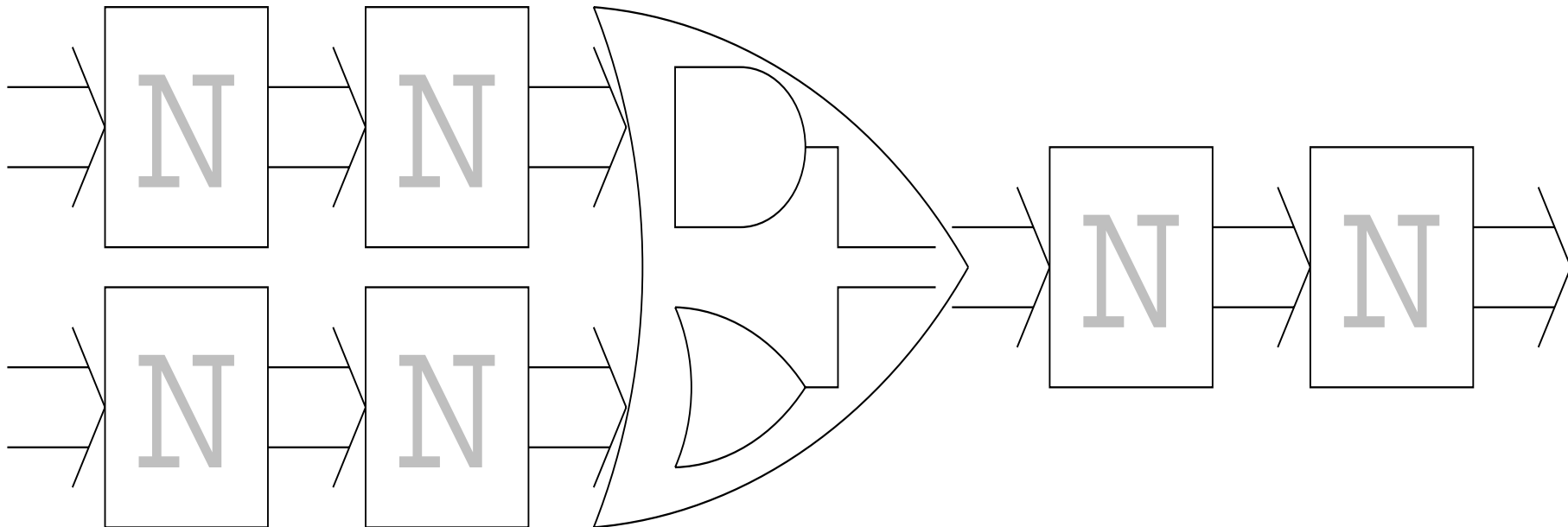
Early Output Logic using Anti-Tokens



Early Output Logic using Anti-Tokens

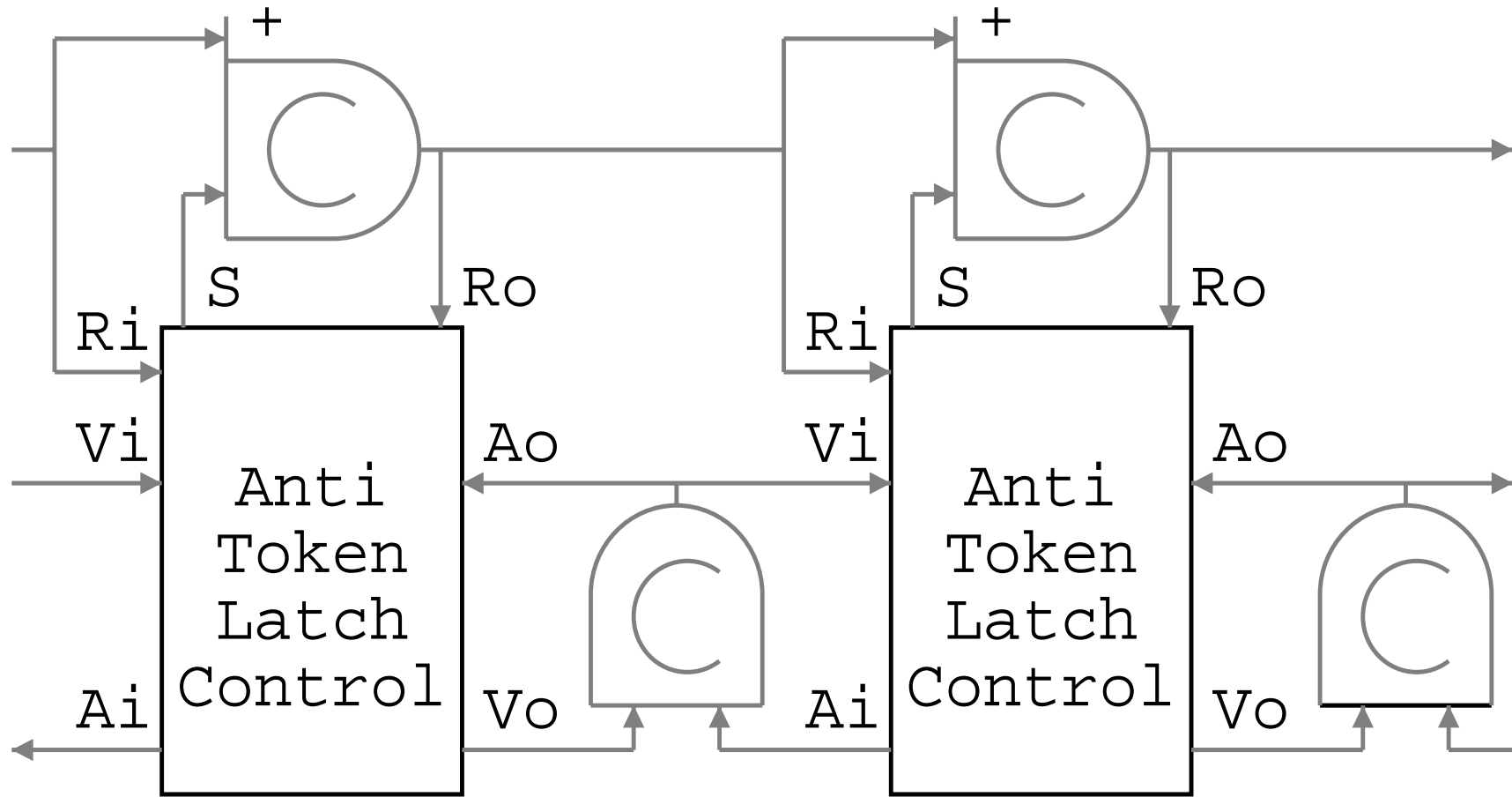


Early Output Logic using Anti-Tokens



Ready to accept next set of inputs

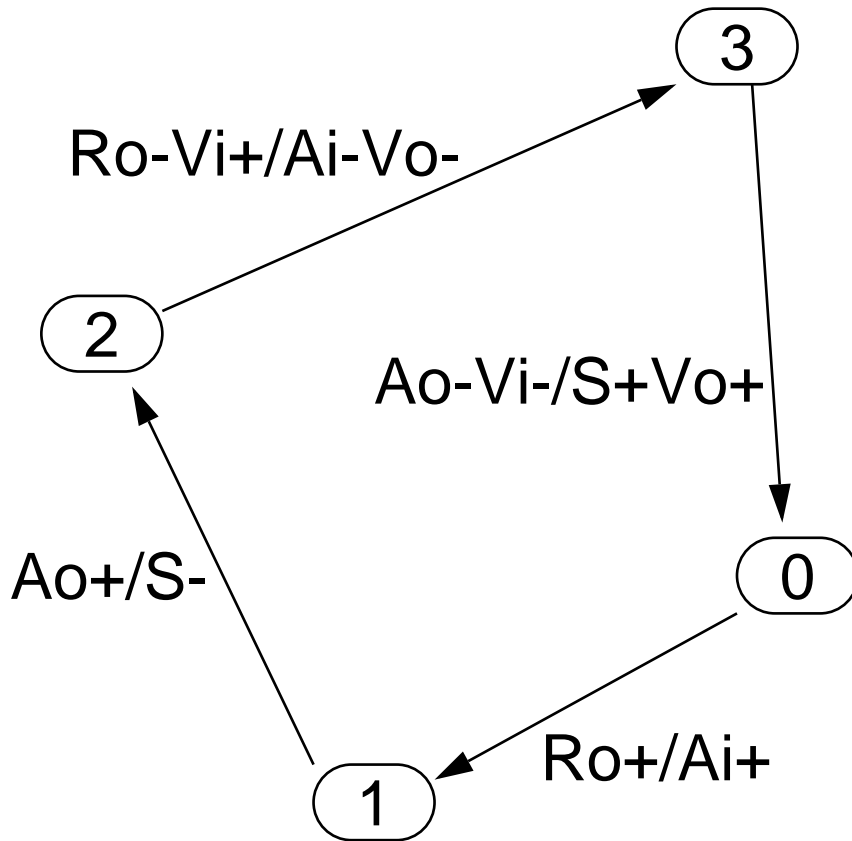
Early Output Logic using Anti-Tokens



Anti-token pipeline

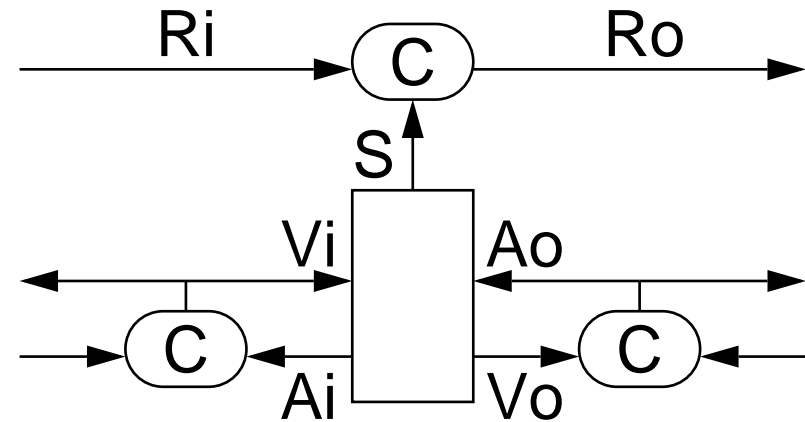


Early Output Logic using Anti-Tokens

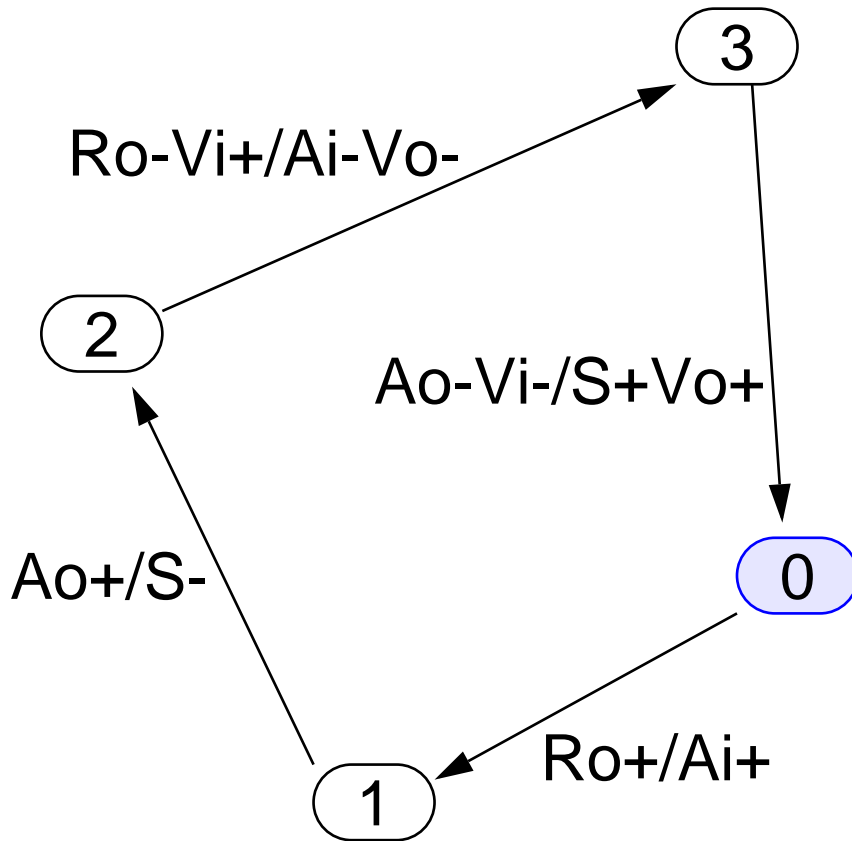


MINIMALIST

Inputs/Outputs



Early Output Logic using Anti-Tokens

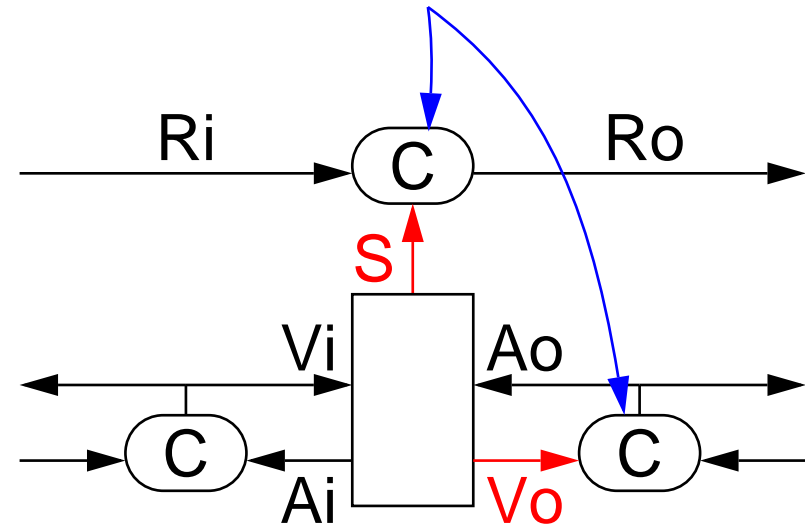


Initial state:0

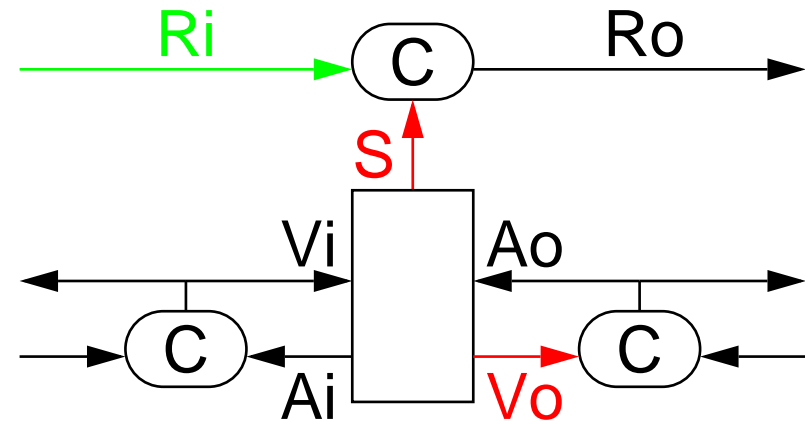
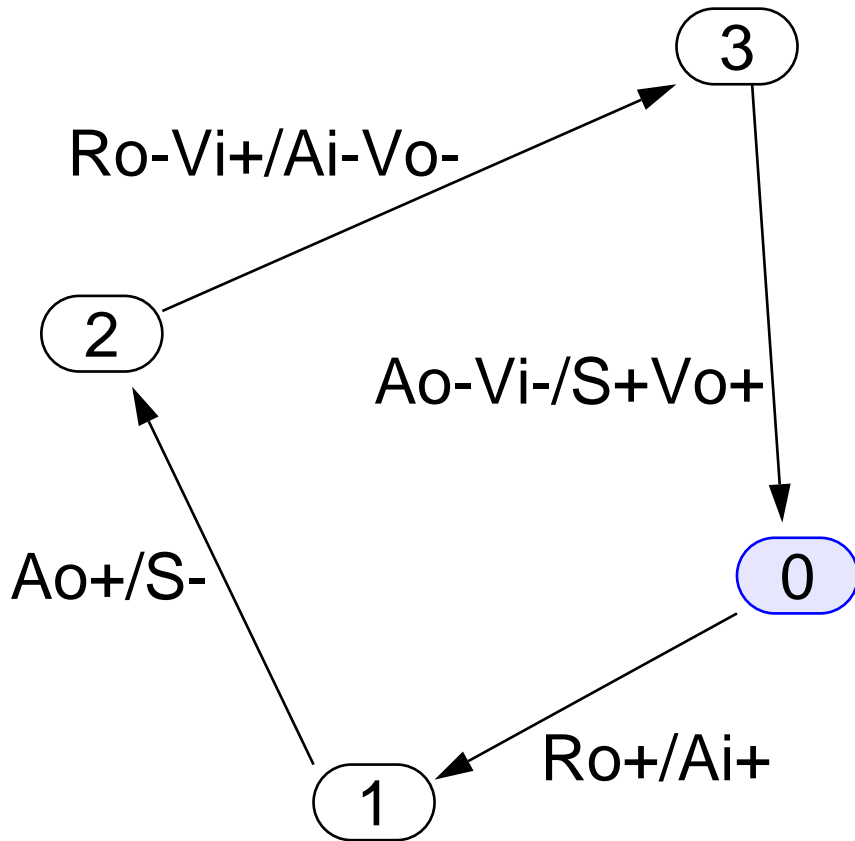
$S, V_o = 1$

$R_i, R_o, V_i, A_i, A_o = 0$

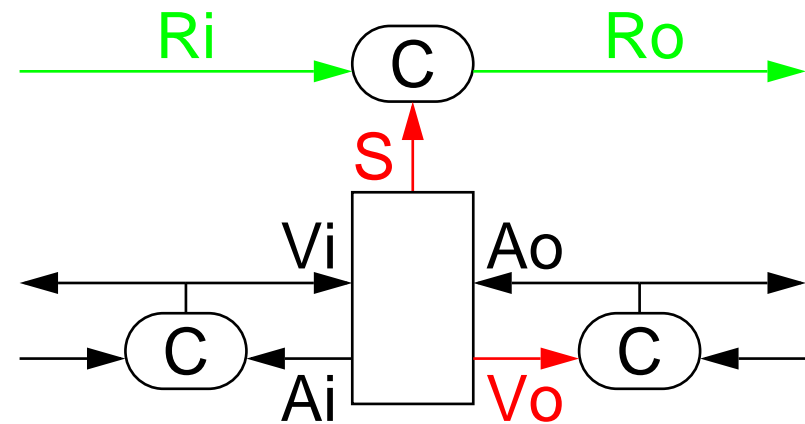
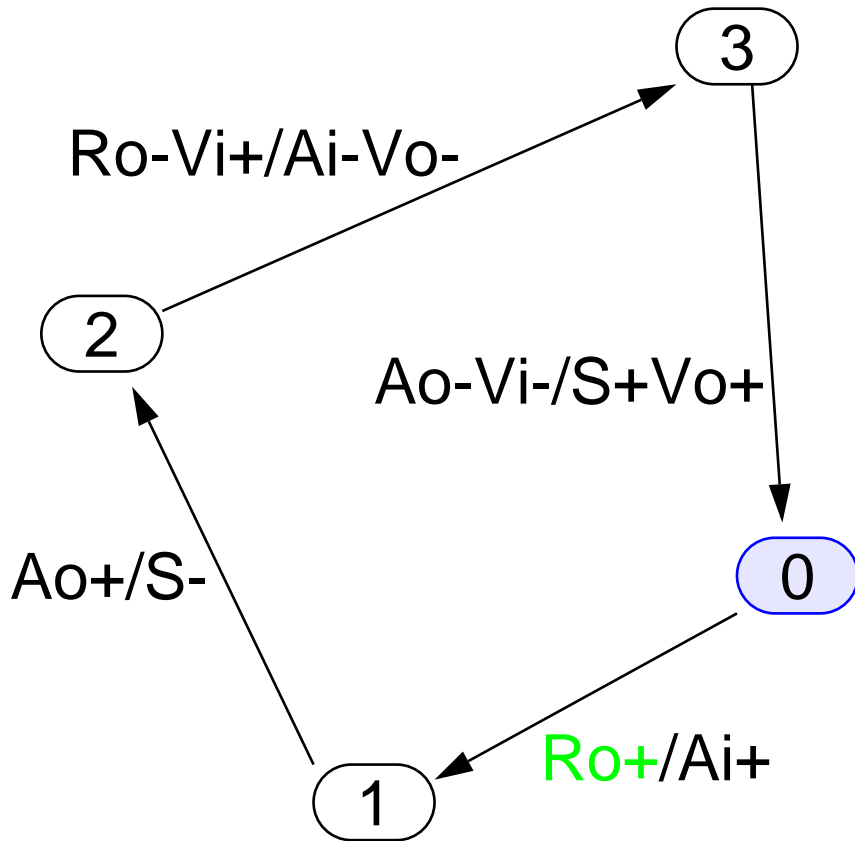
Note:Both C-elements primed to fire



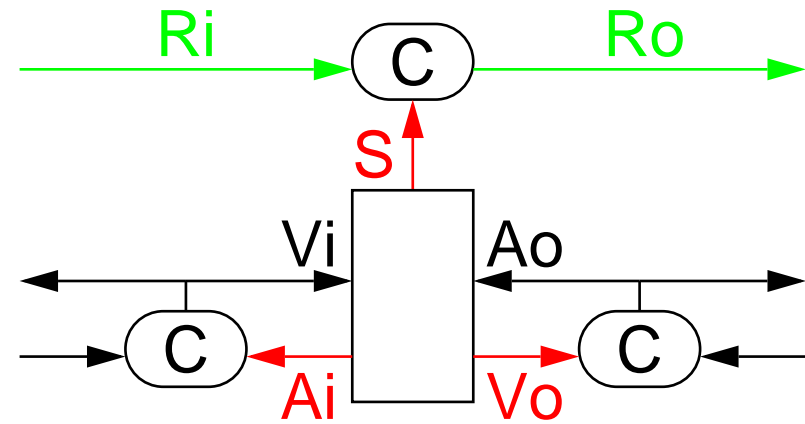
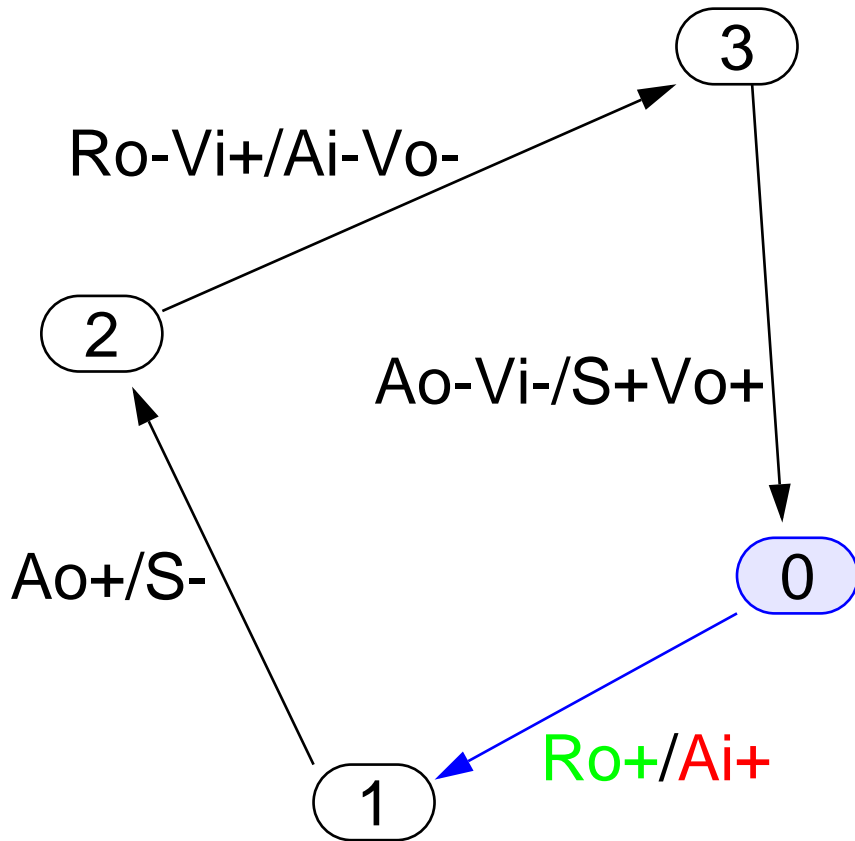
Early Output Logic using Anti-Tokens



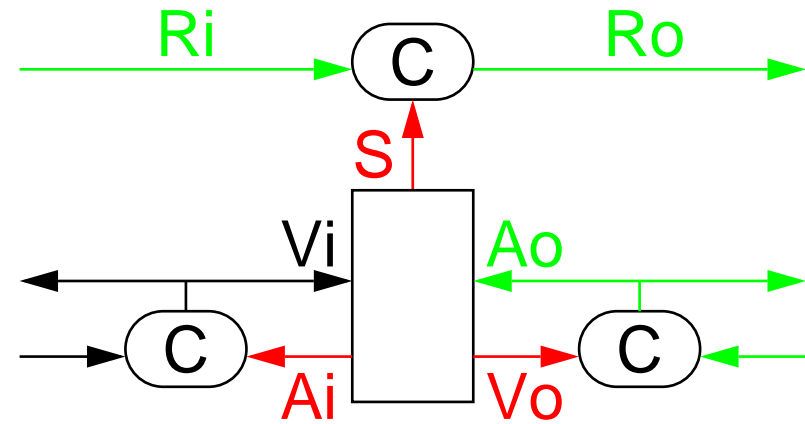
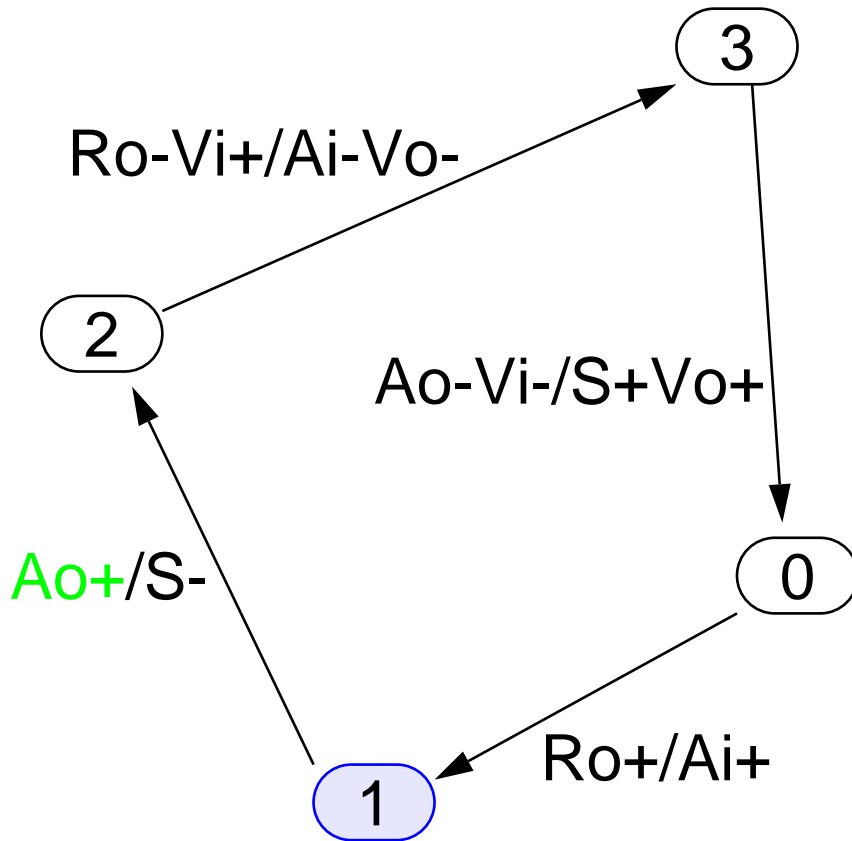
Early Output Logic using Anti-Tokens



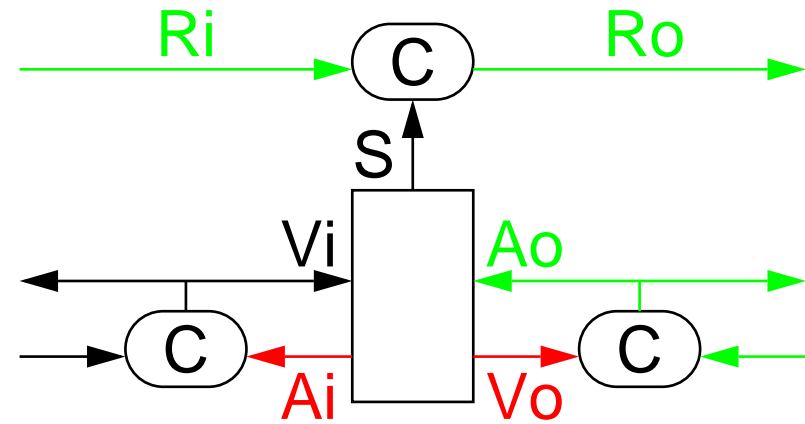
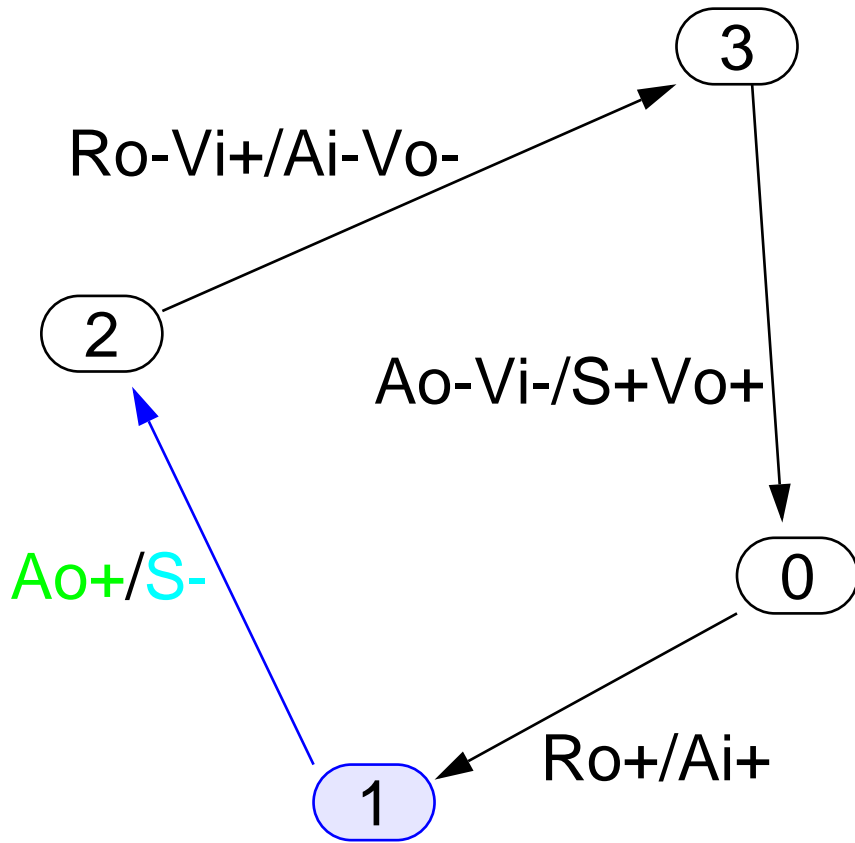
Early Output Logic using Anti-Tokens



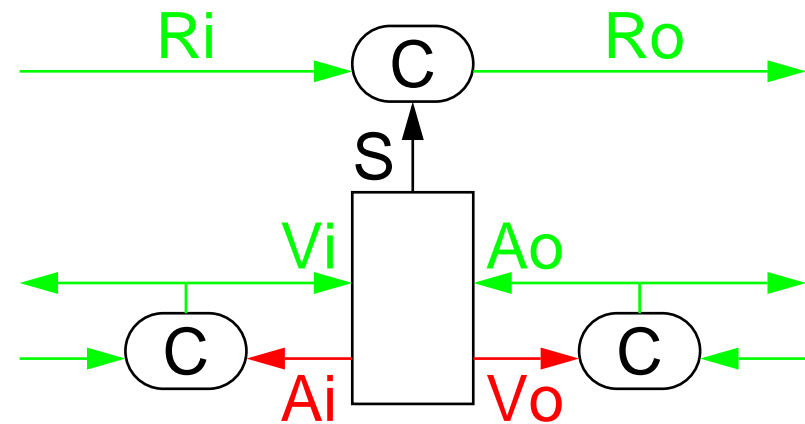
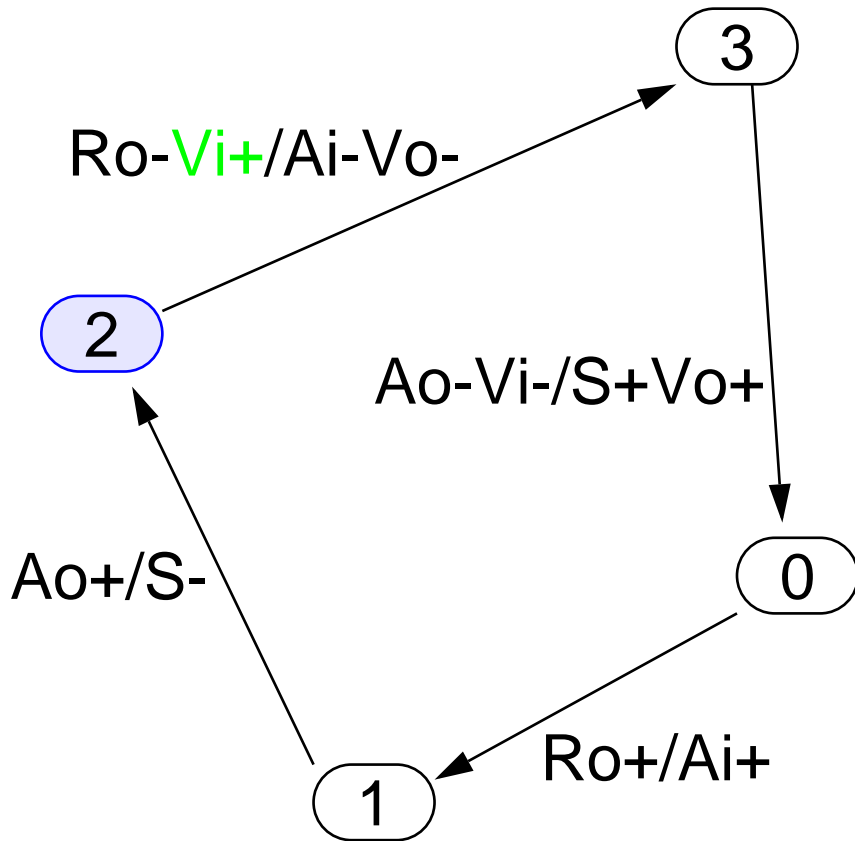
Early Output Logic using Anti-Tokens



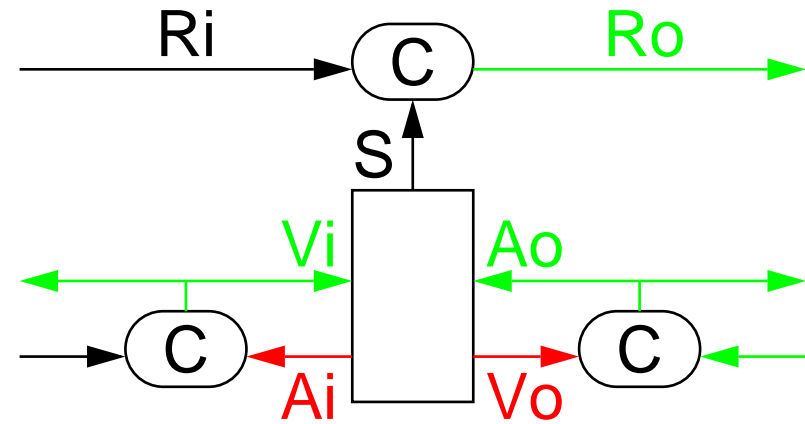
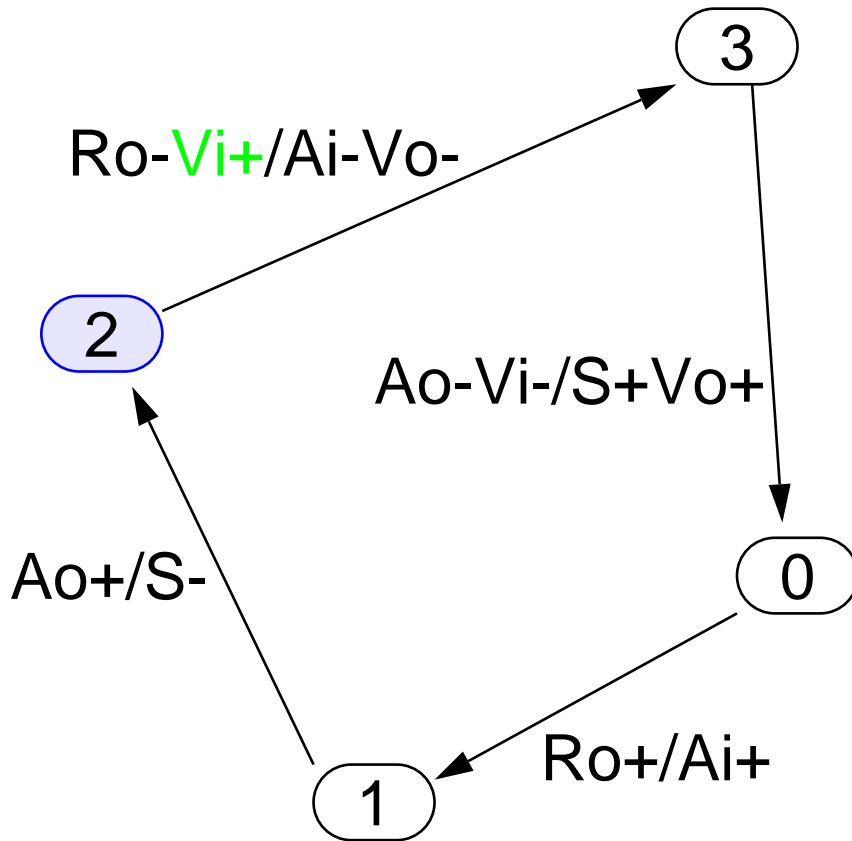
Early Output Logic using Anti-Tokens



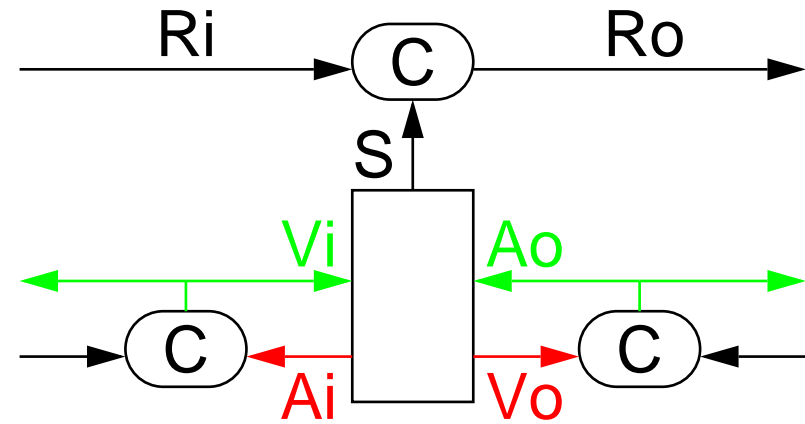
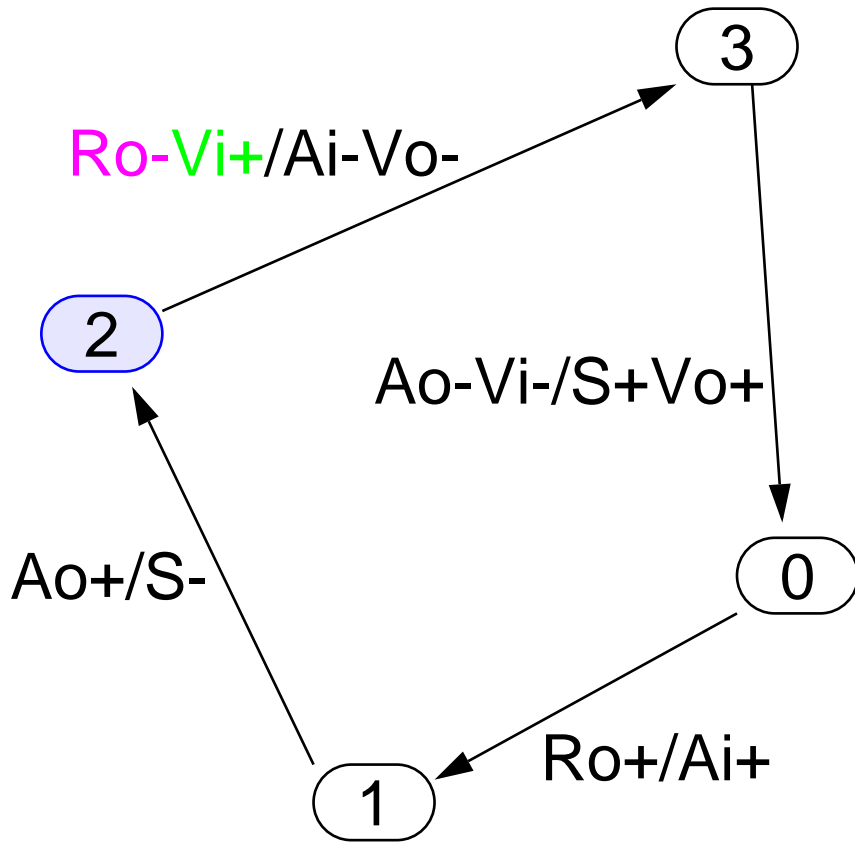
Early Output Logic using Anti-Tokens



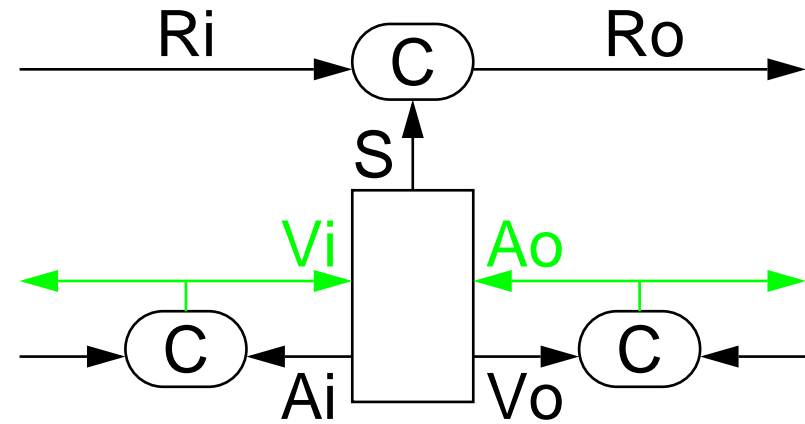
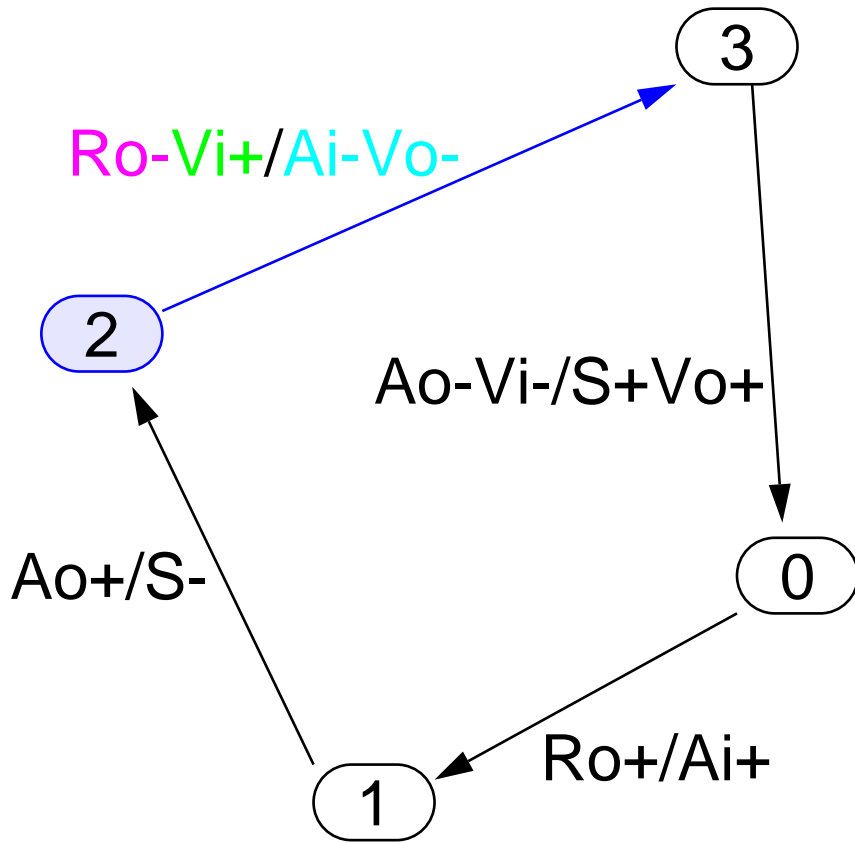
Early Output Logic using Anti-Tokens



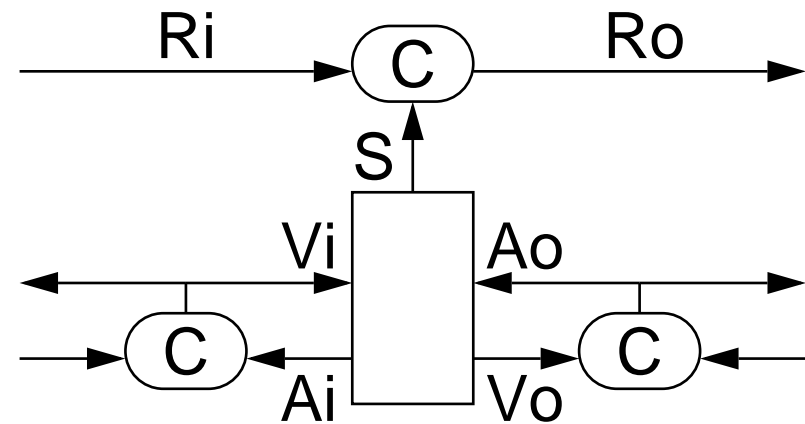
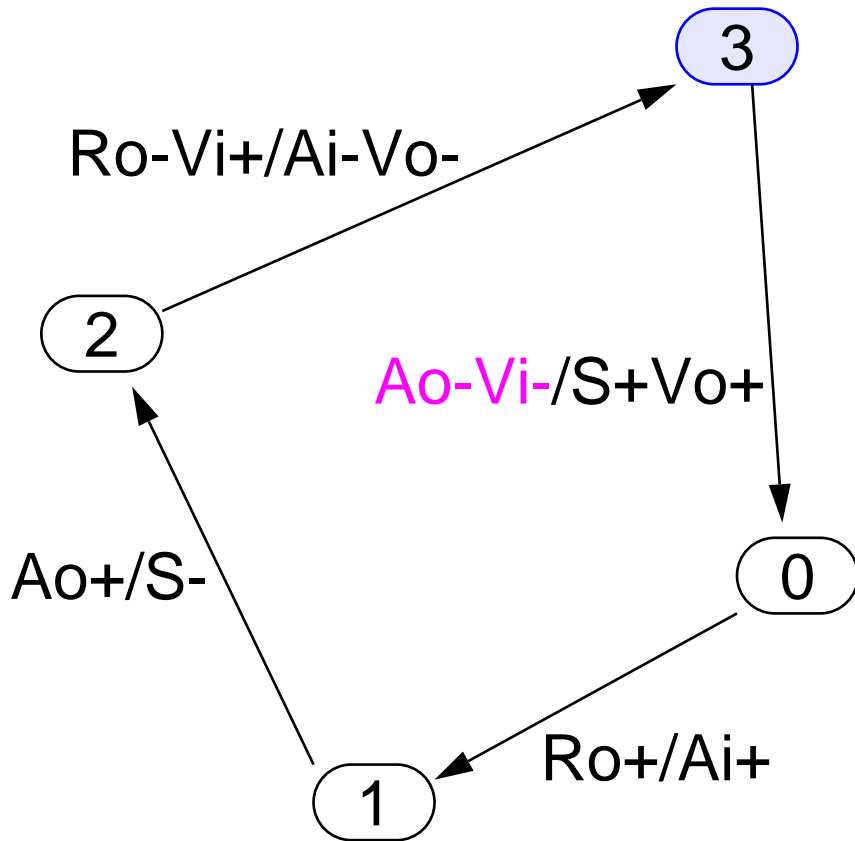
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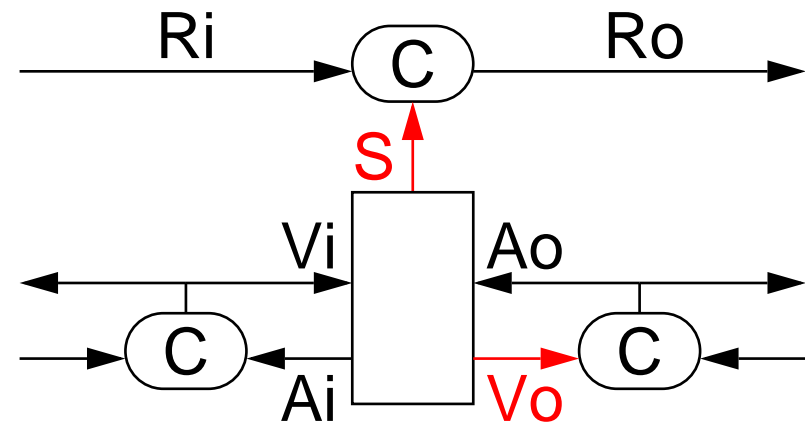
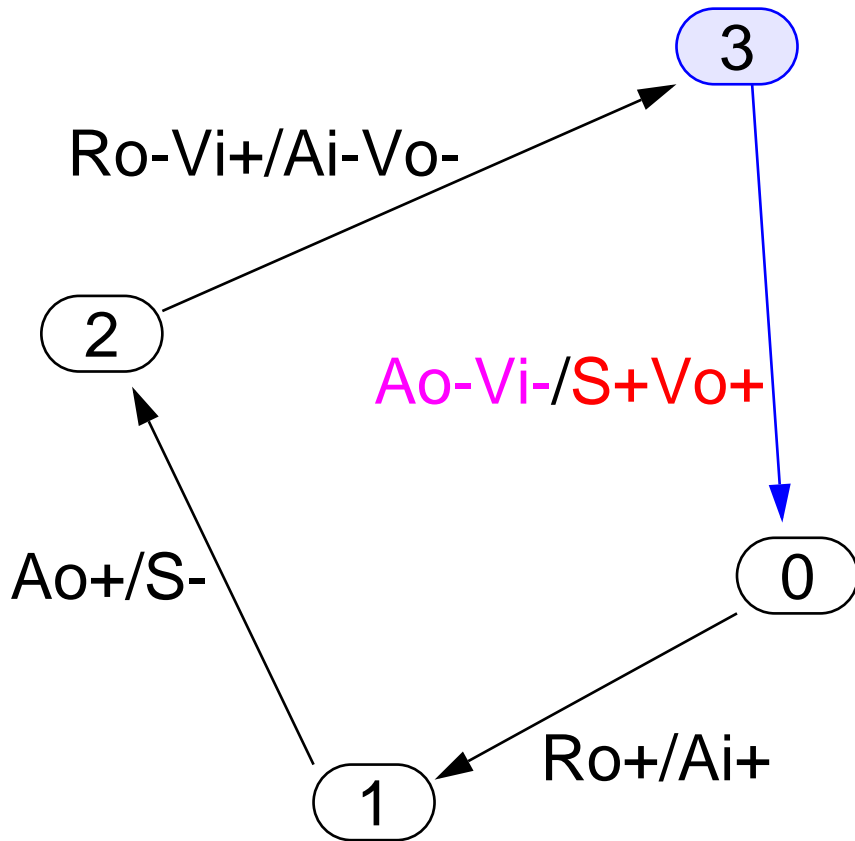
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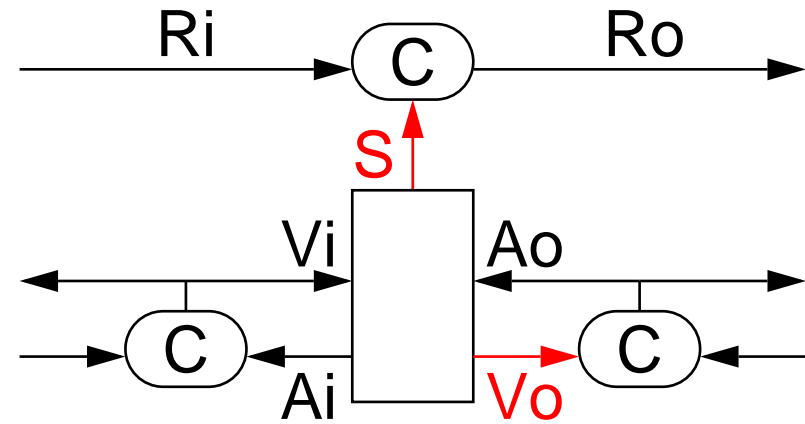
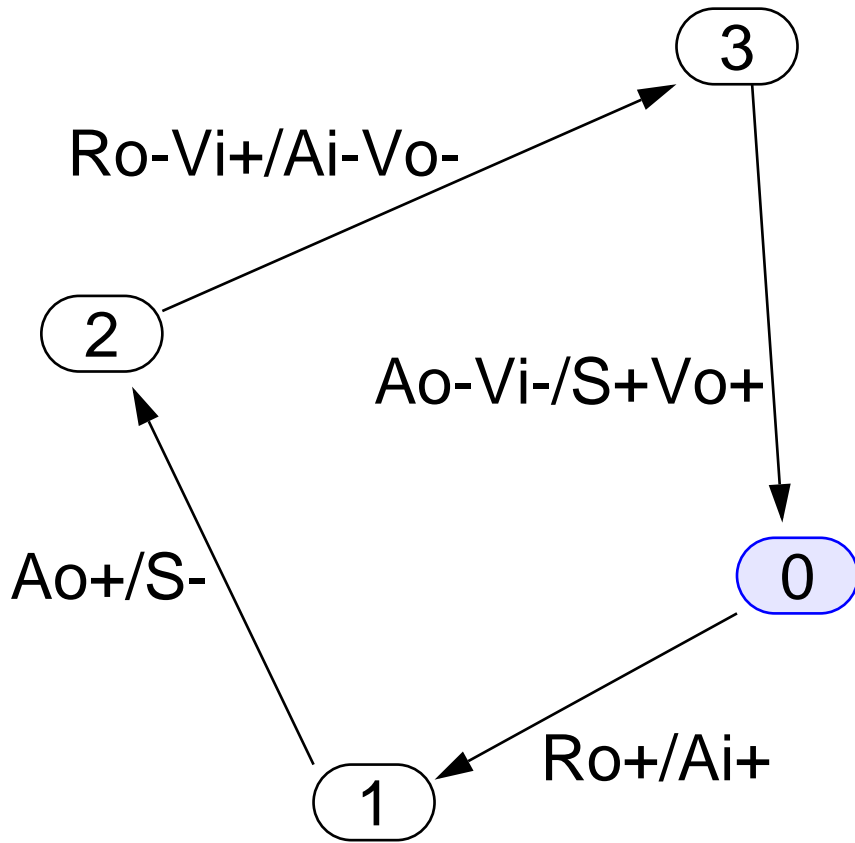
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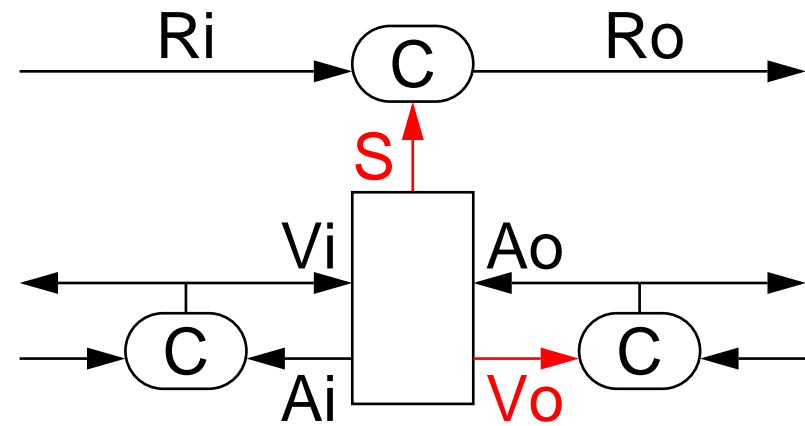
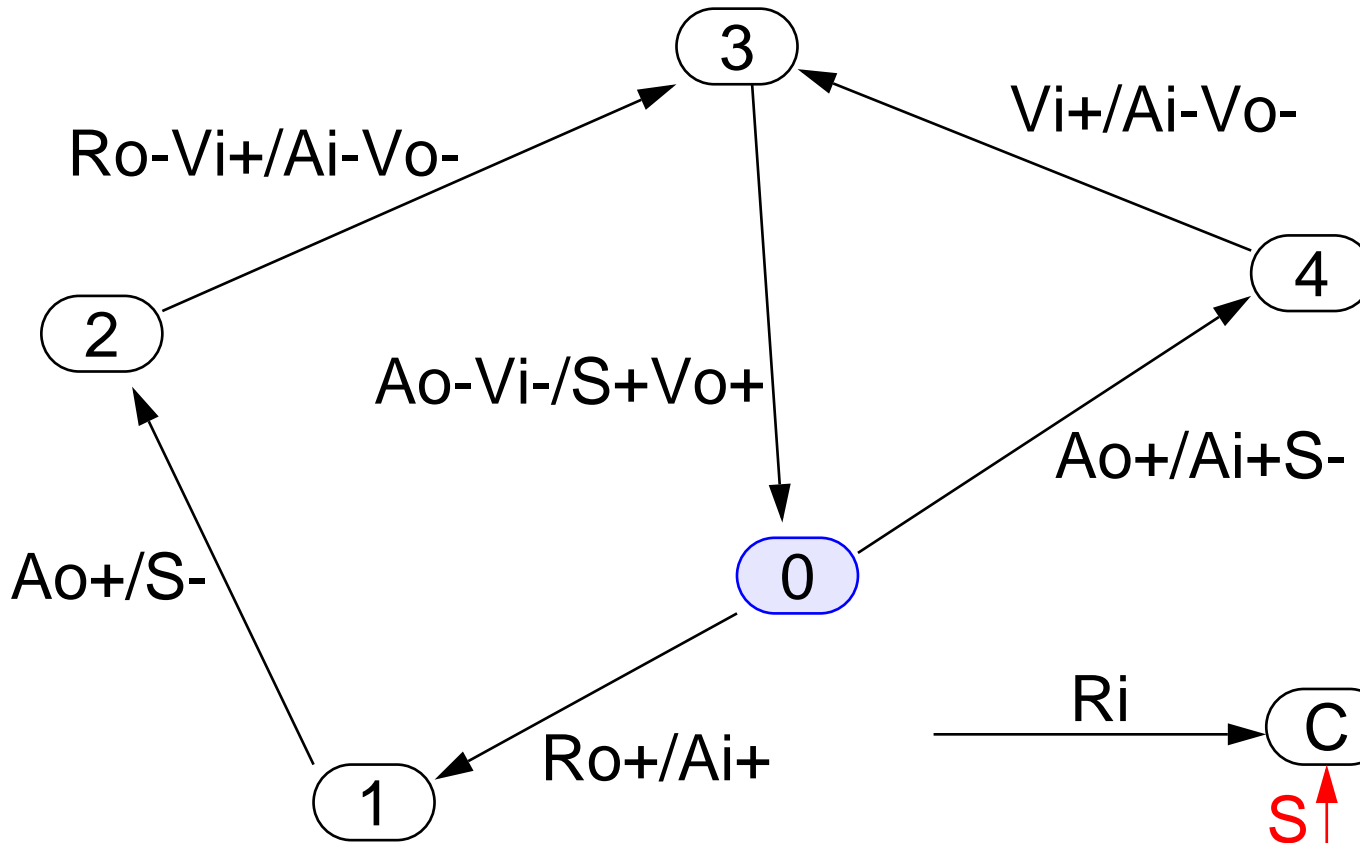
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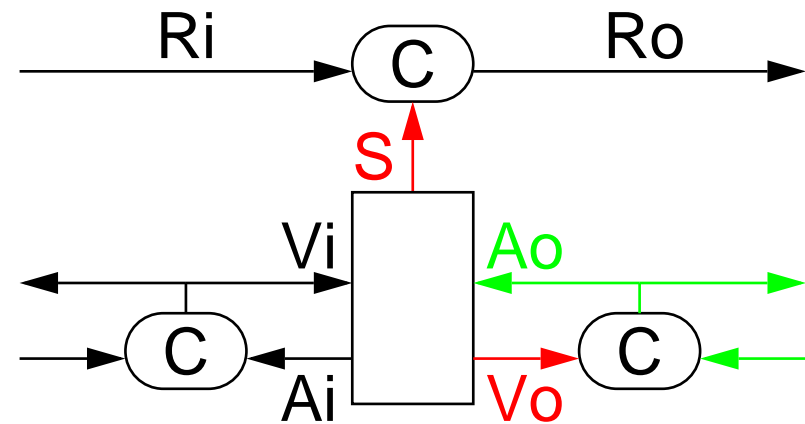
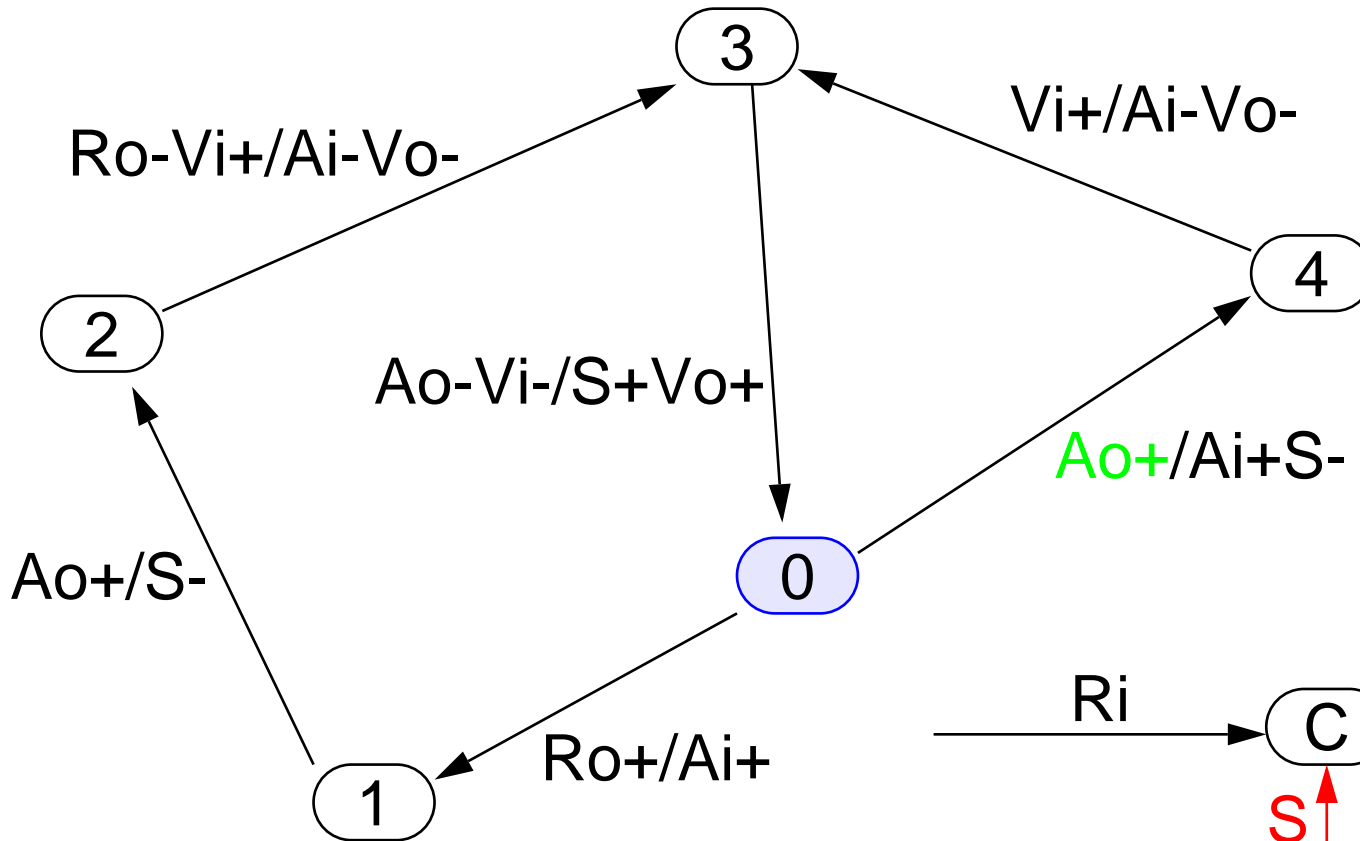
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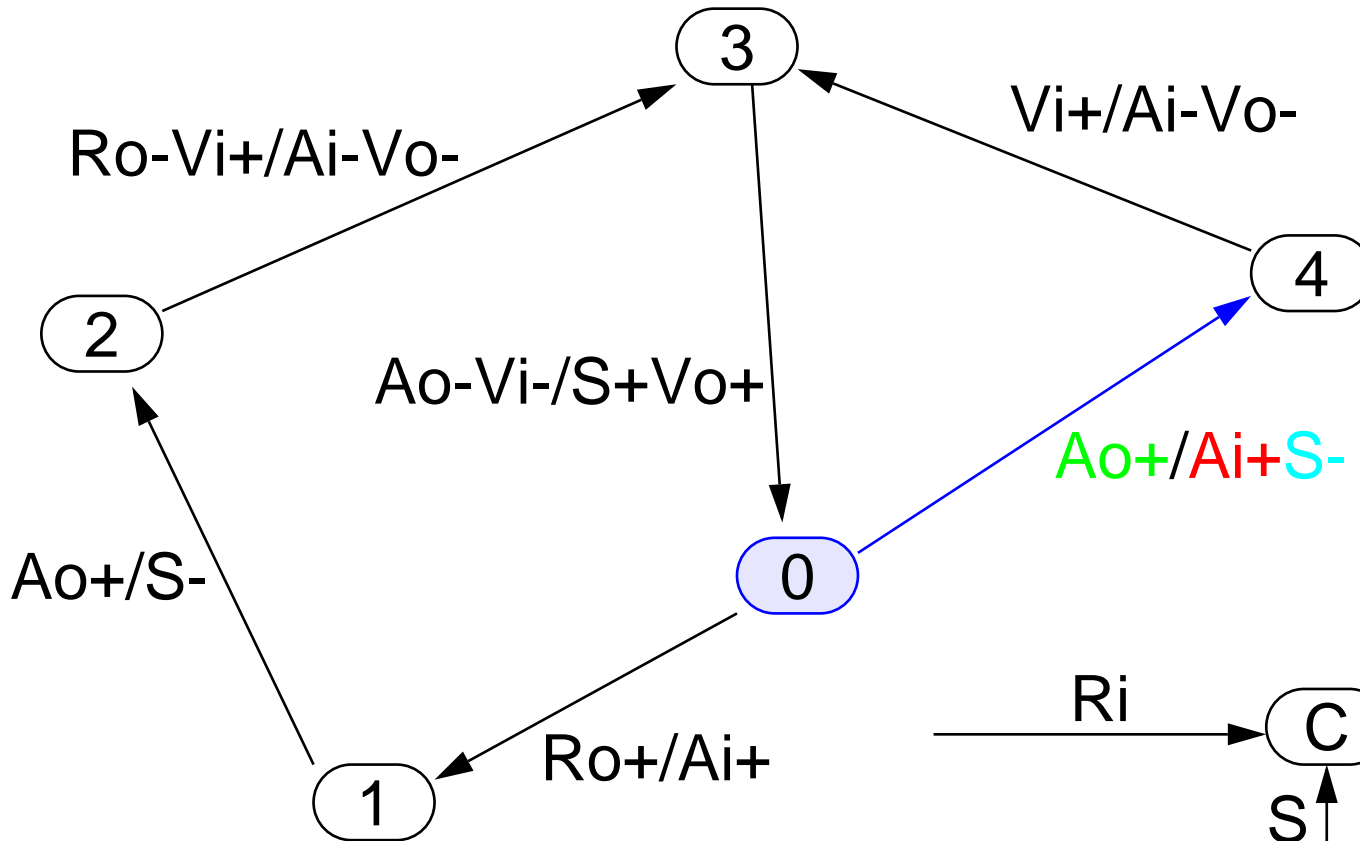
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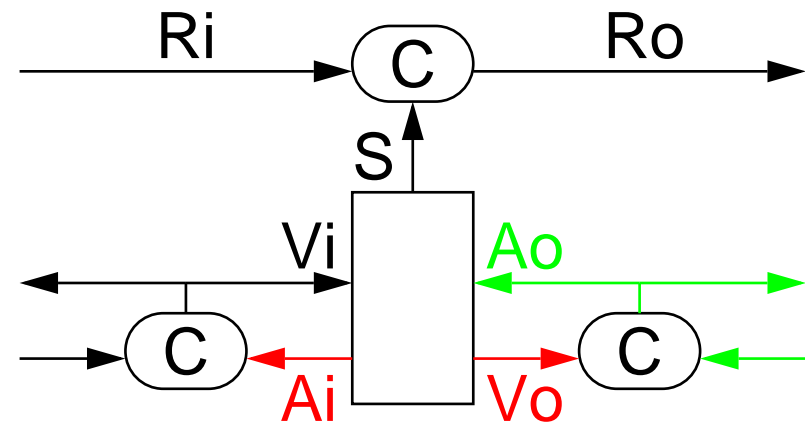
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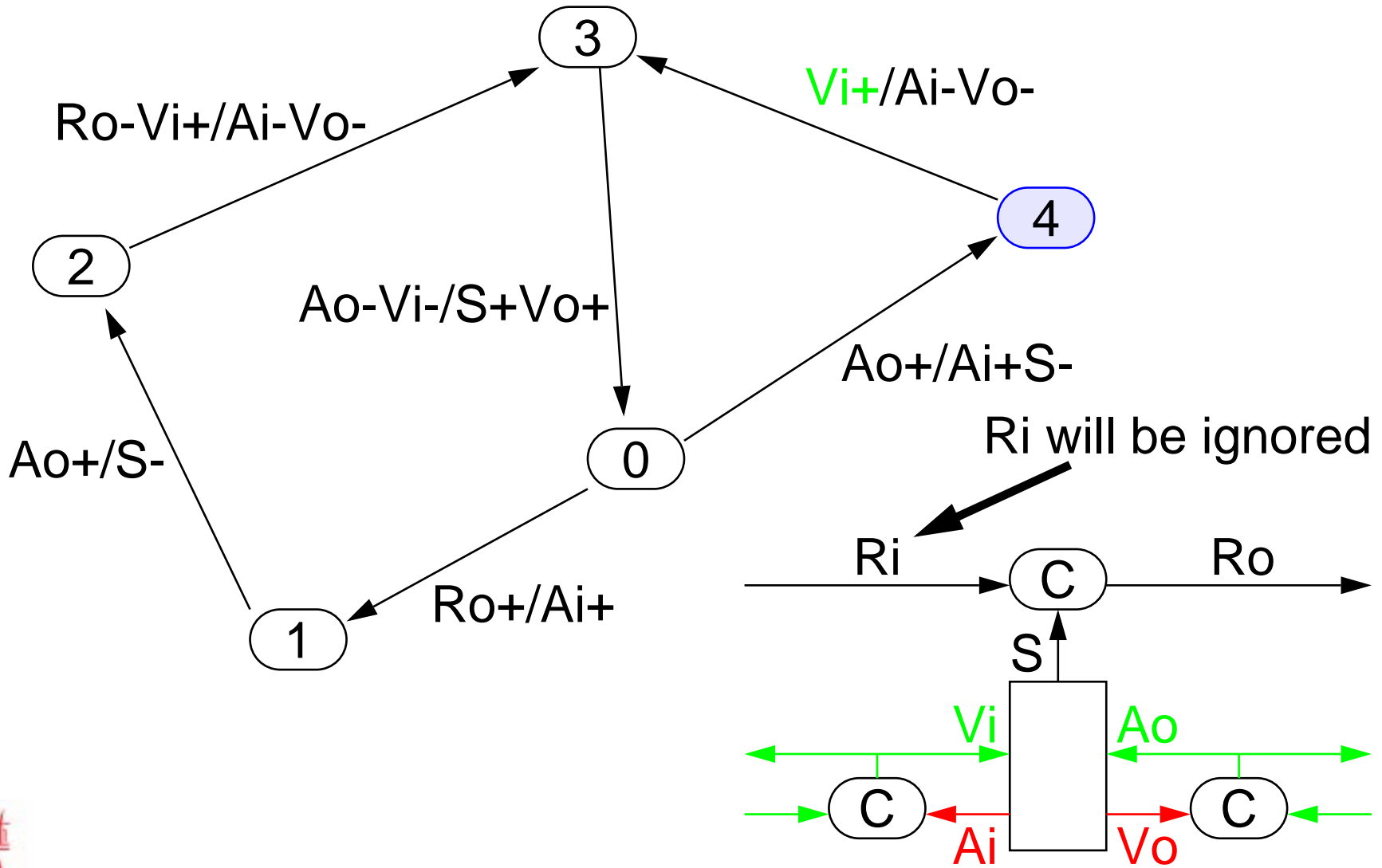
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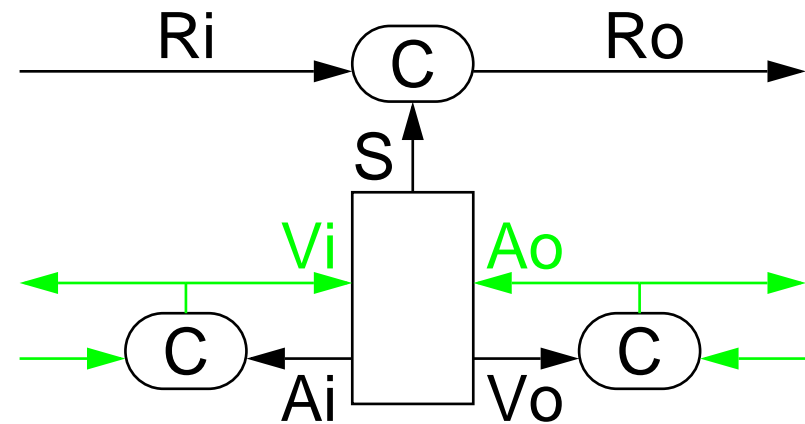
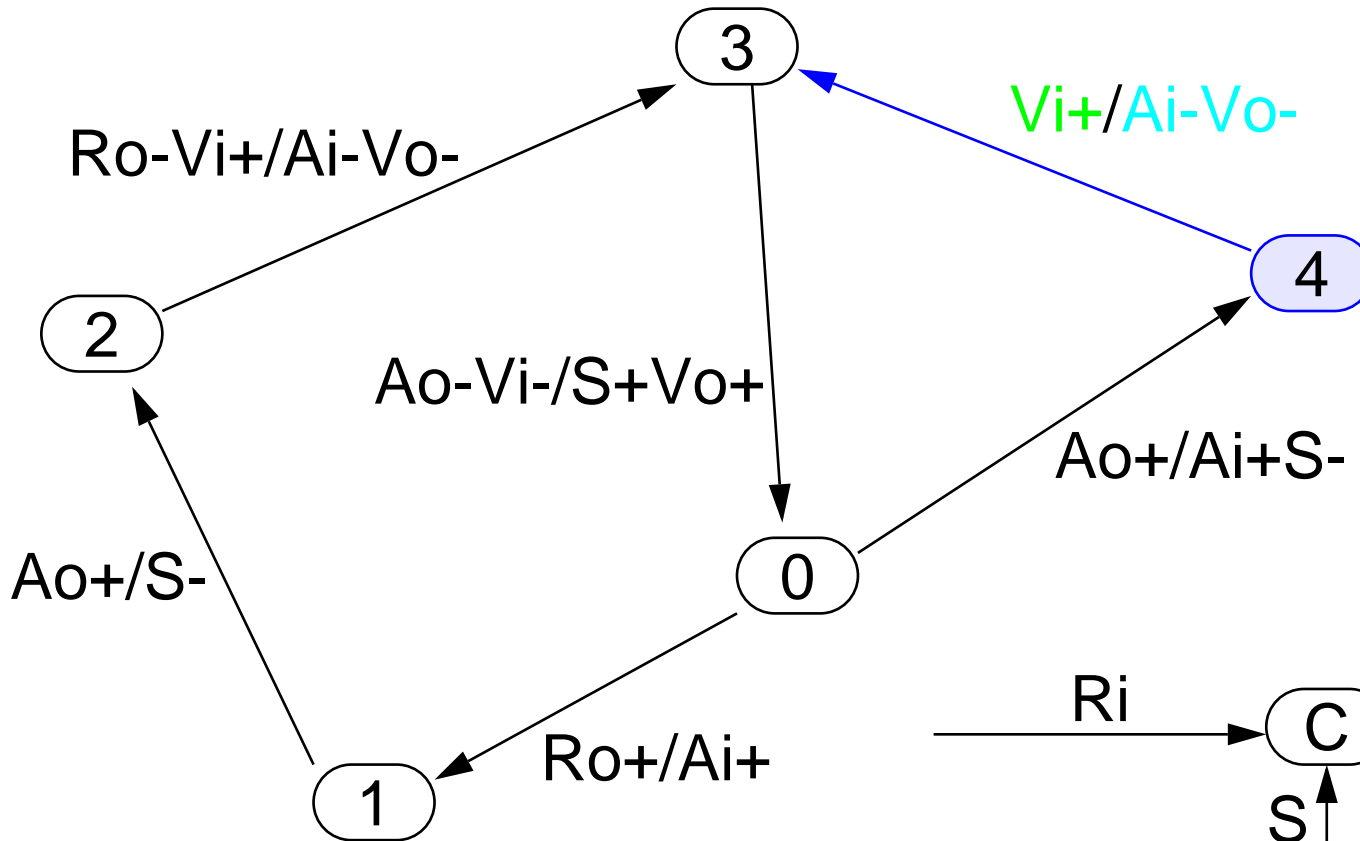
Withdraw S
Metastability



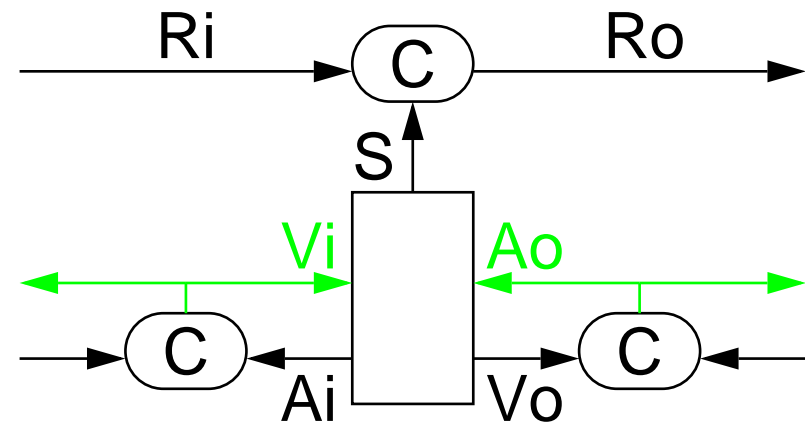
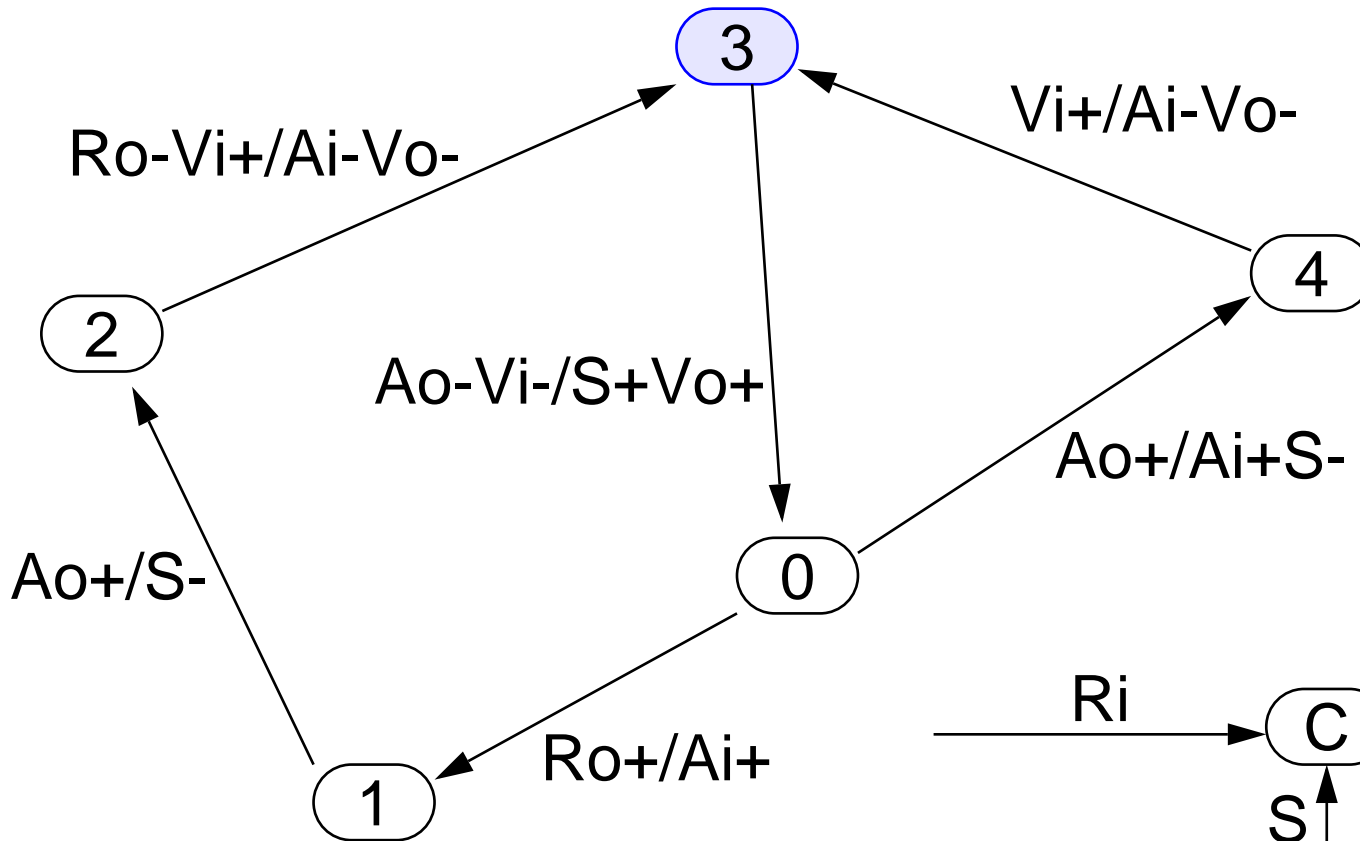
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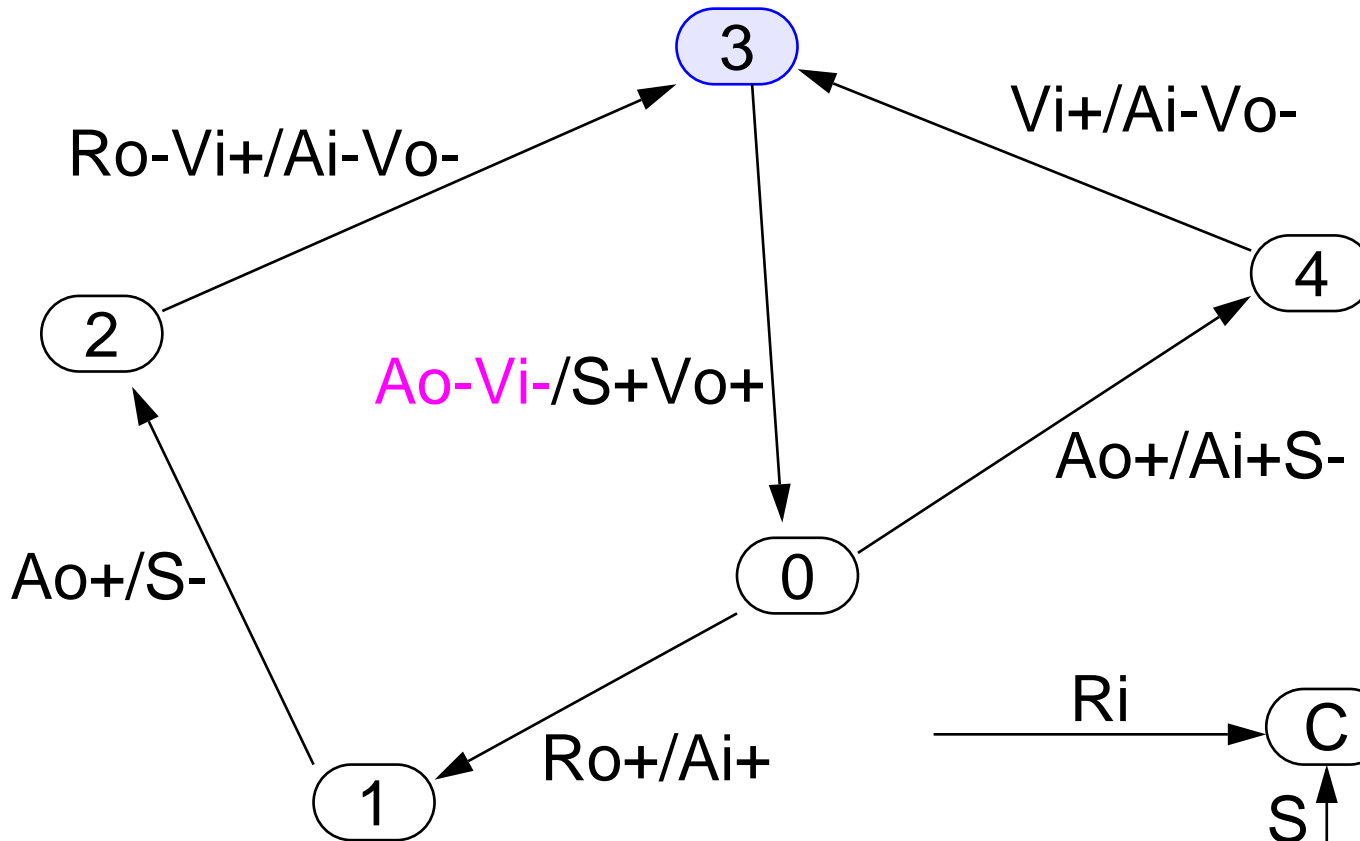
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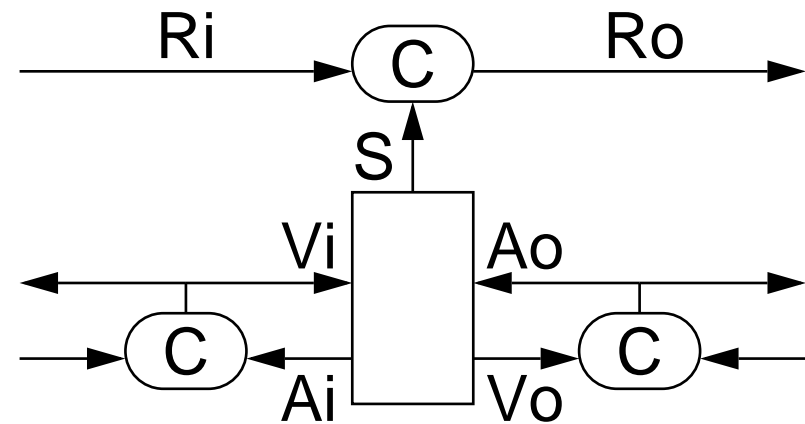
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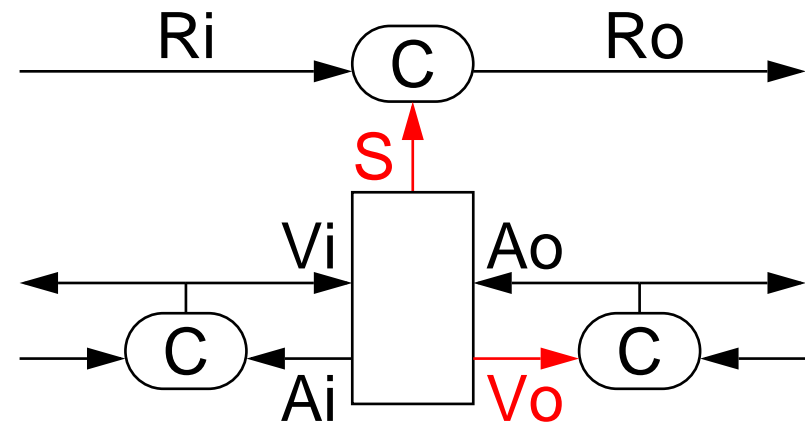
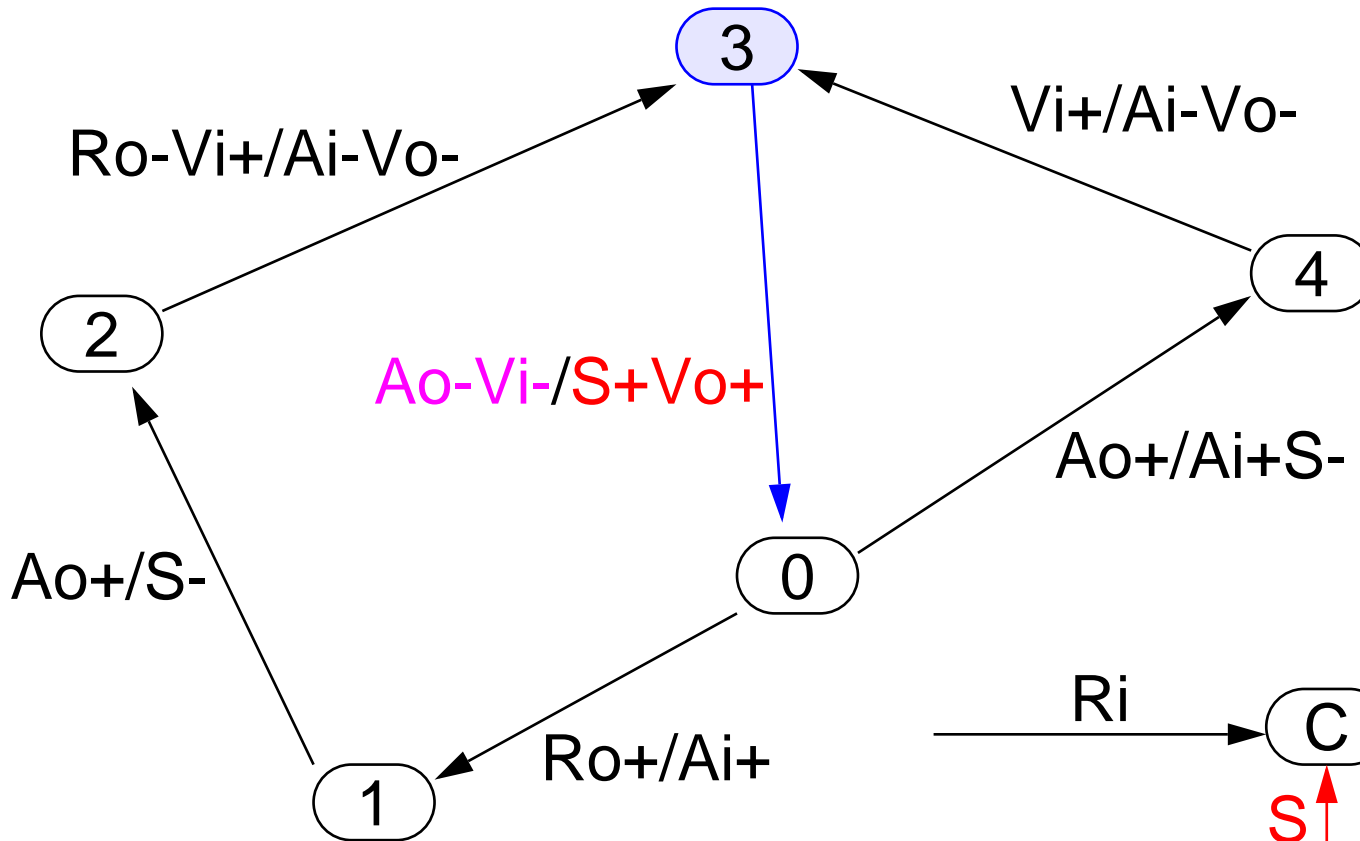
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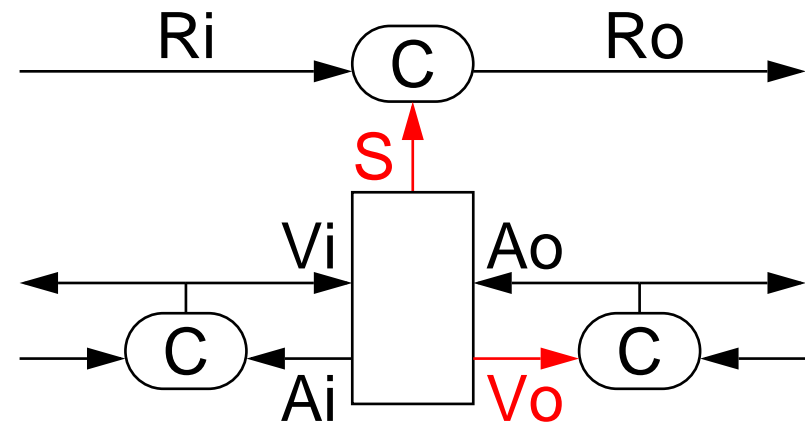
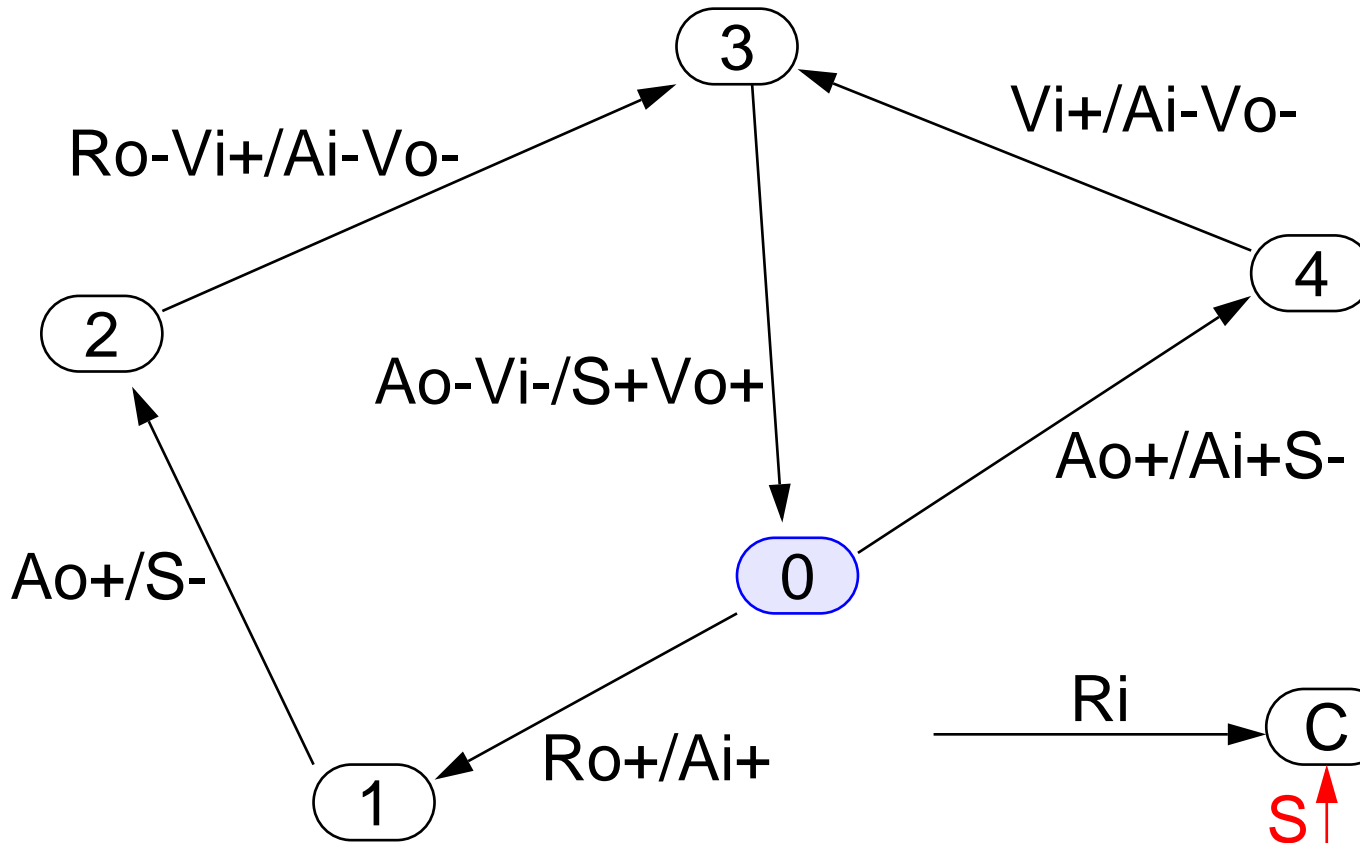
Keep 'Vo' and 'S' low until ready



Early Output Logic using Anti-Tokens



Early Output Logic using Anti-Tokens



Summary

Early output logic

Early output cases

Better semi-decoupled latches

Remove synchronisation

Anti-tokens

Arbiter free