COMP311: *COMPUTER ORGANIZATION!*

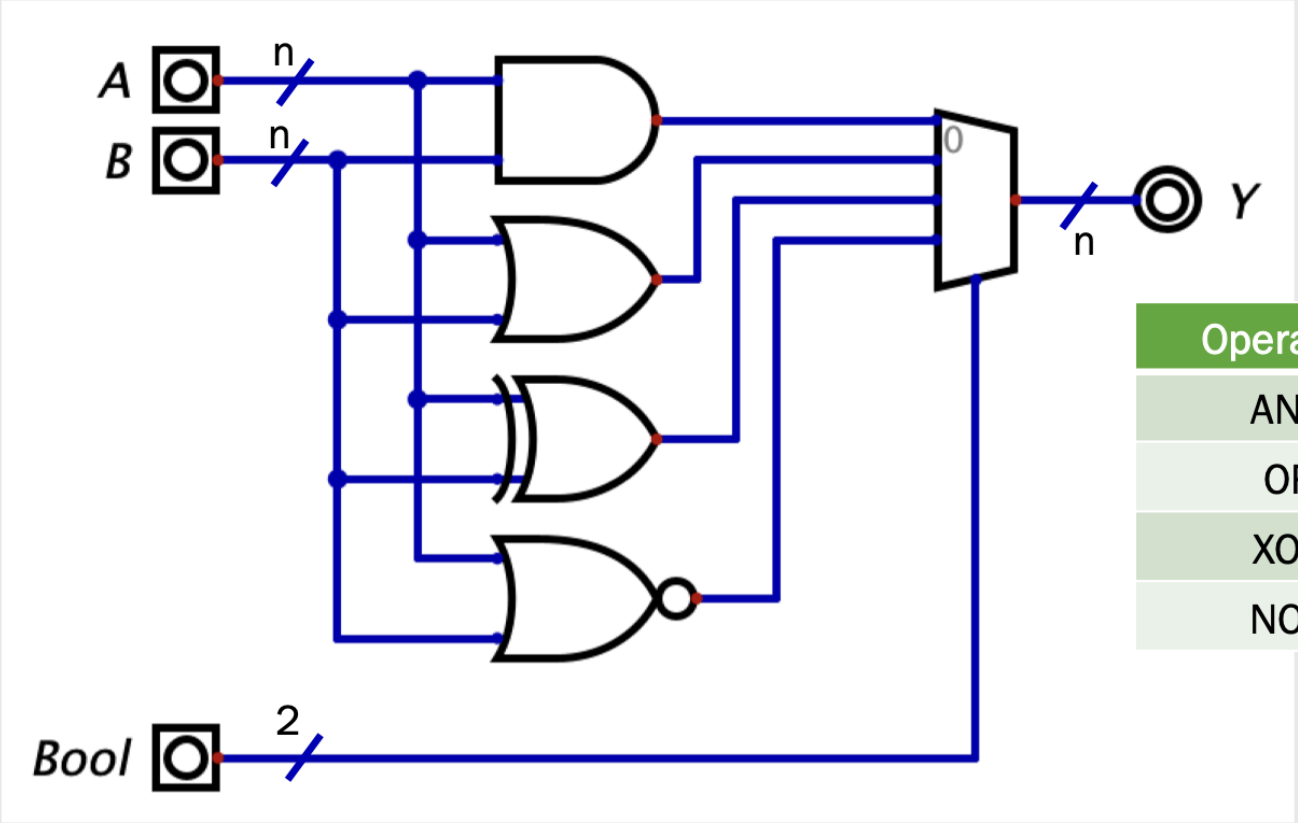
Lecture 14: Registers, Timing Analysis

tinyurl.com/comp311-fa25

Quiz Topics!

- K-maps (review!)
- Multiplexers (review!)
- Adder/Subtractor Circuits
- Shifter Circuits
- Comparator Circuits
- Tracing through an ALU
- Timing / Waveform Diagrams
  - *With propagation delay*
- Circuit design!
  - *Given a specification, implement a familiar circuit using known components*
  - *Familiarity with circuits we have designed together in class, in the labs*
  - *given a new control table for the ADD/SUB, SHIFT, or BOOL units, you should be able to re-wire it accordingly*

Boolean Unit



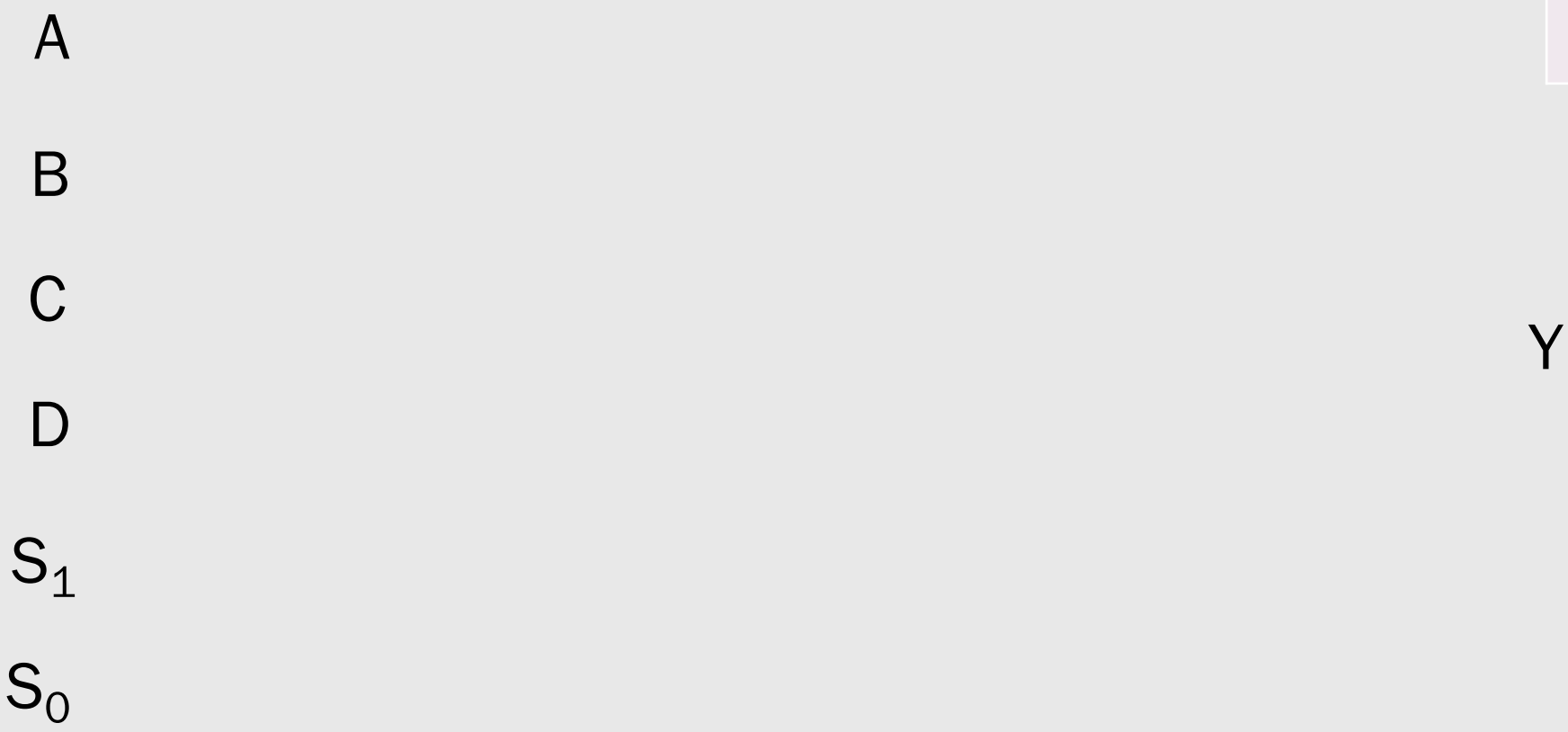
Operation	Expression	Bool
AND	A x B	0b00
OR	A + B	0b01
XOR	$A \oplus B$	0b10
NOR	$\overline{A + B}$	0b11

Multiplexers Review

Multiplexers Review

- Create a 4:1 multiplexer out of 2:1 multiplexers.

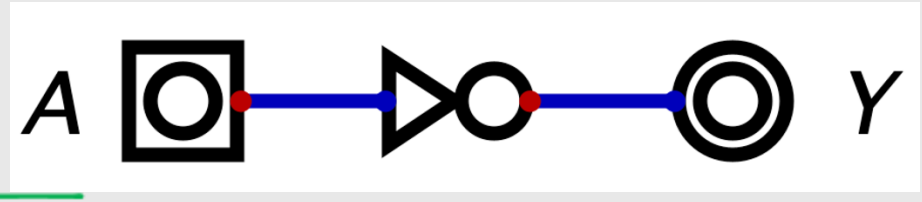
S1	S0	Y
0	0	A
0	1	B
1	0	C
1	1	D



PROPAGATION DELAY

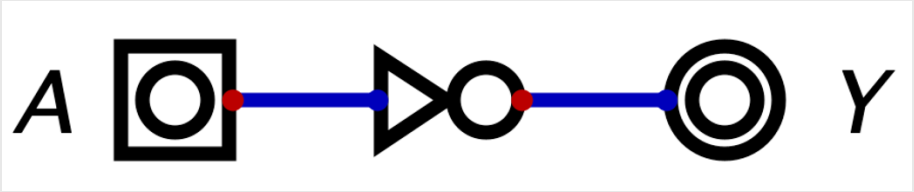
Propagation delay (t_{pd})

- When we change the input to this inverter, the output will not change immediately.
- There will be a delay before the output changes



Propagation delay (t_{pd})

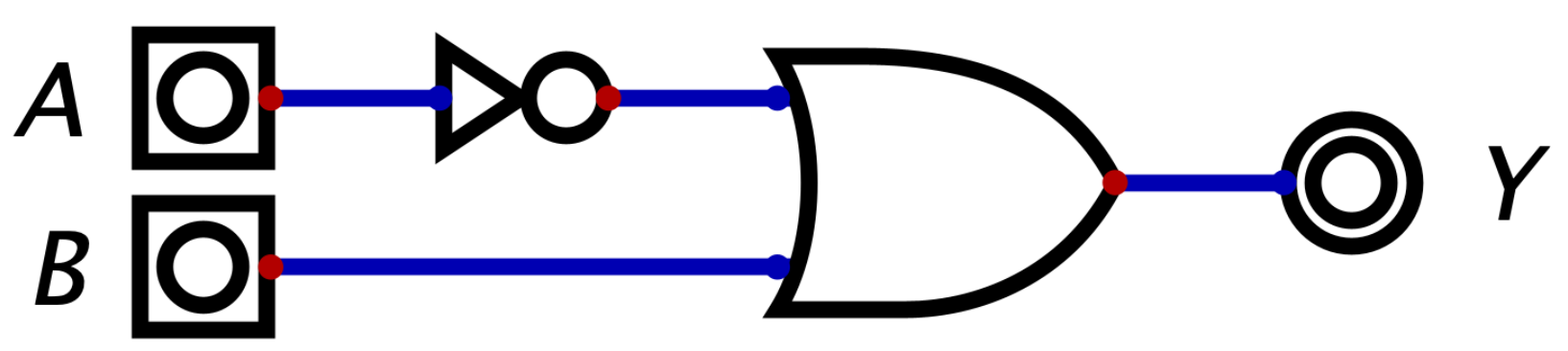
- Let's say the input to this inverter starts at 0.
- When we change the input to 1, the output will not become 0 immediately. There will be a delay.



A: 0 → 1

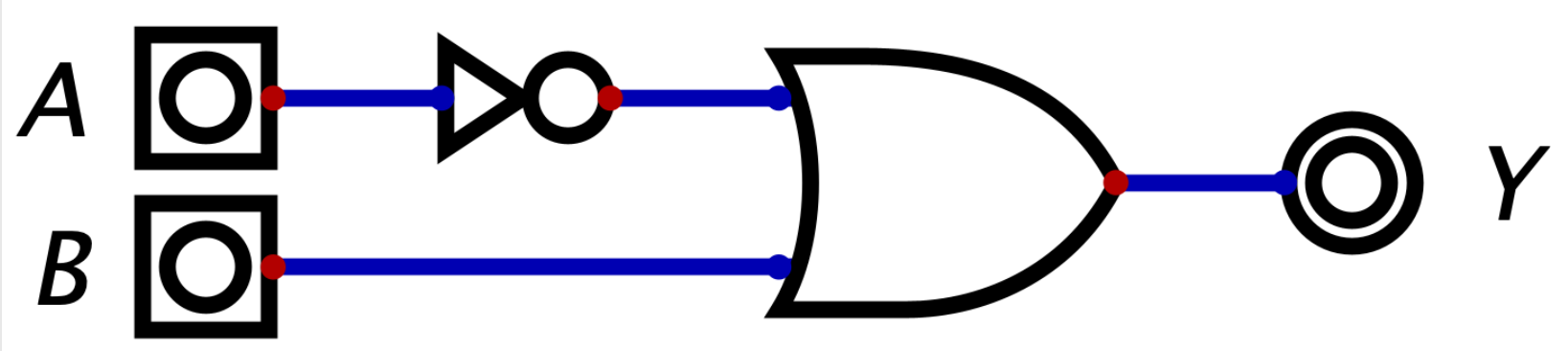
Y: 1 → 0

Ex1: Computing Total Propagation Delay



Gate	t_{pd} (ps)
NOT	10
OR	20

Ex1: Computing Total Propagation Delay



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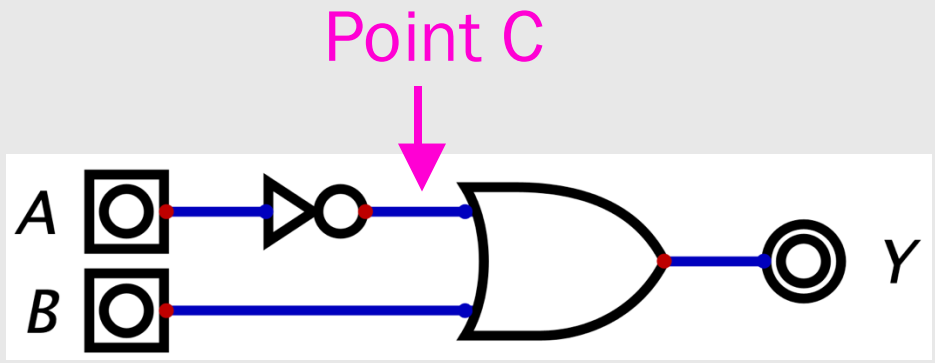
Delay from A to Y = 10ps + 20ps = 30ps

Delay from B to Y = 20ps

Ex1: Waveform Diagram with Propagation Delay



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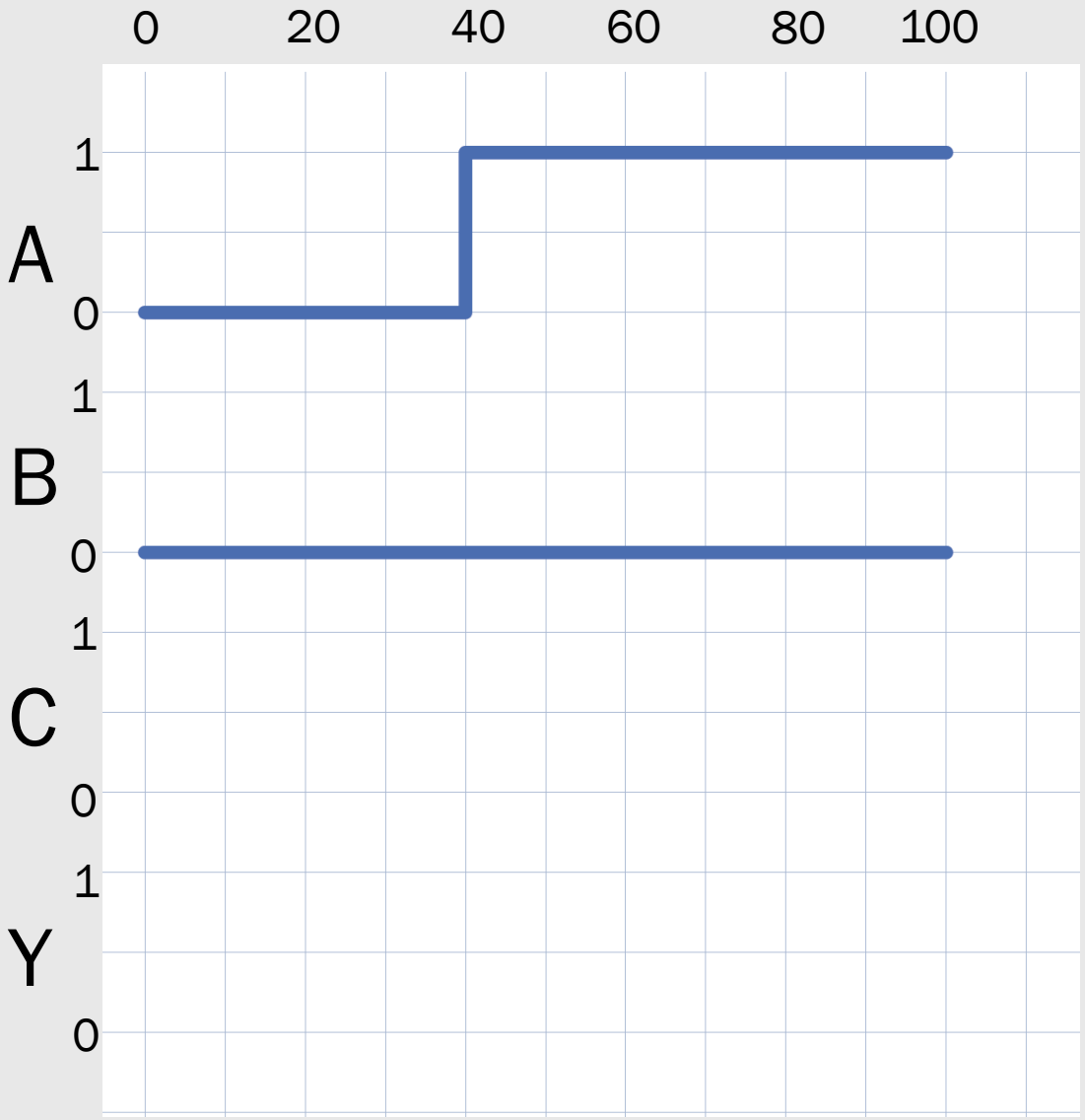

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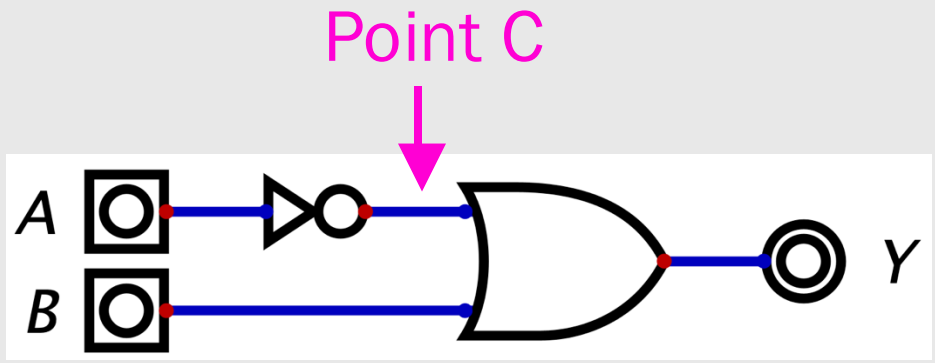

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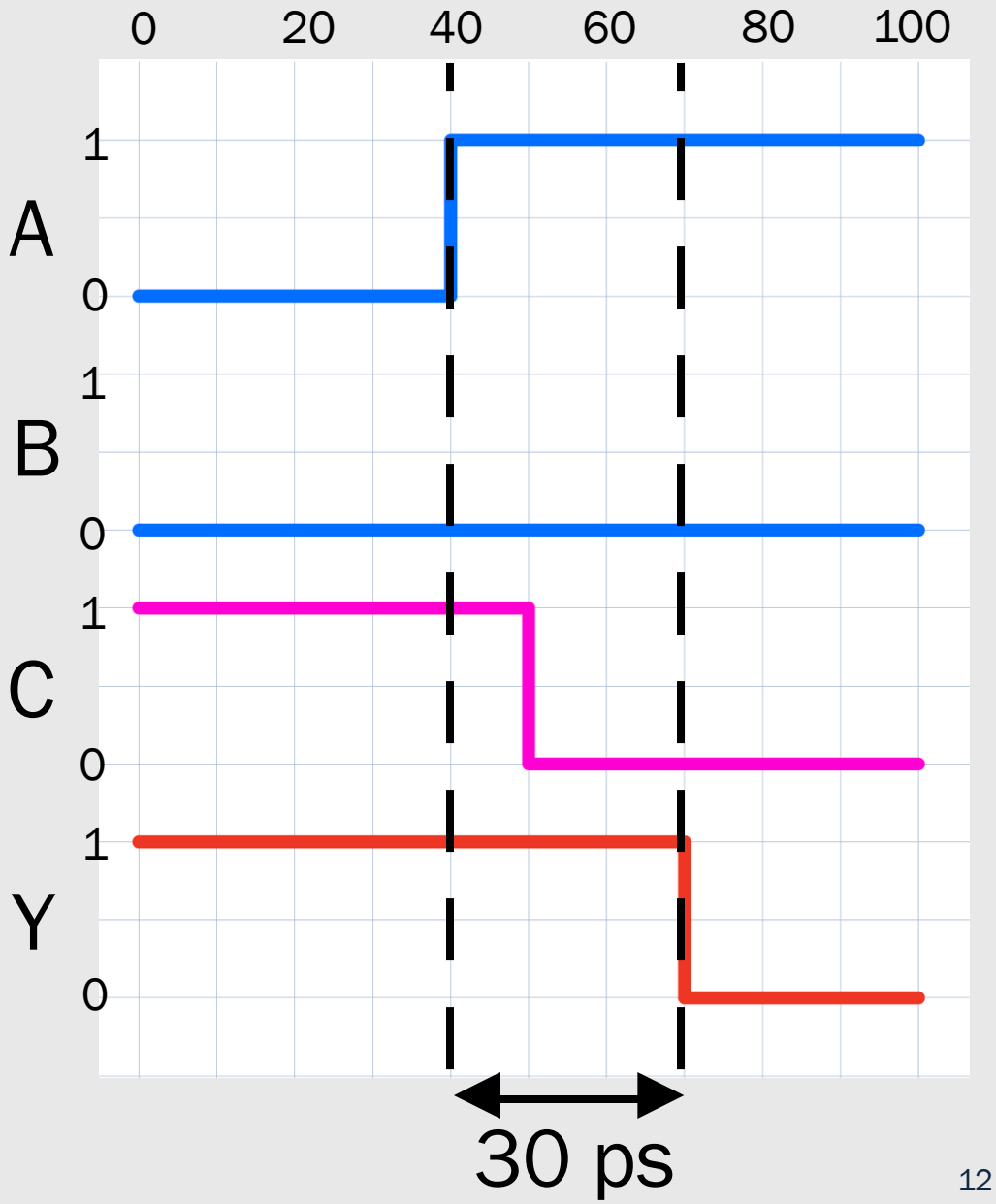
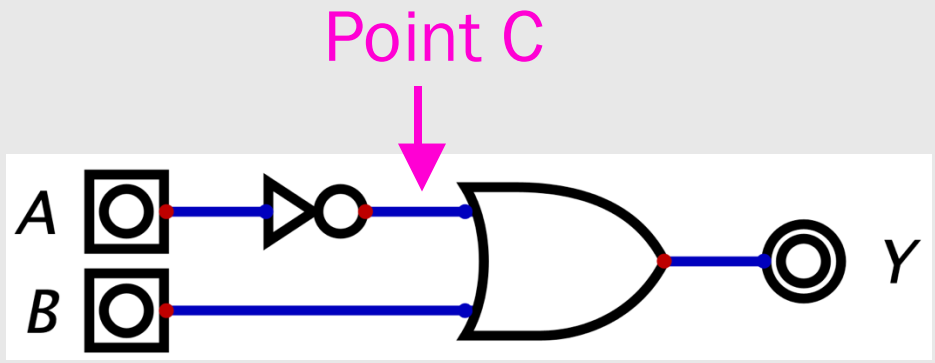


Ex2: Waveform Diagram with Propagation Delay



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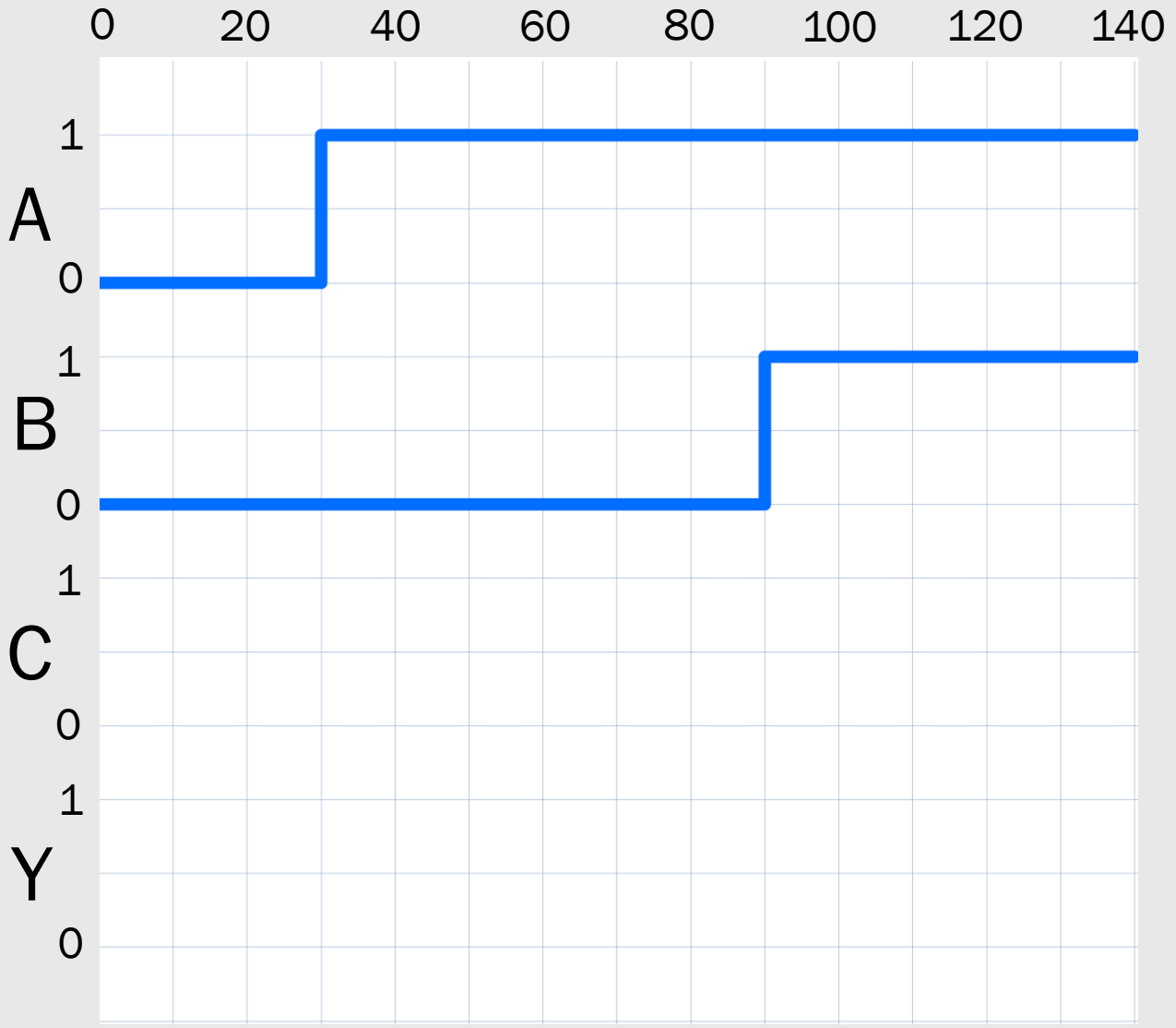

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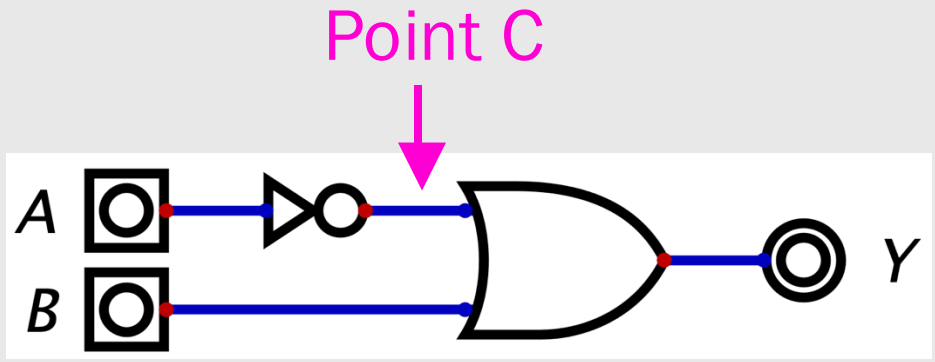

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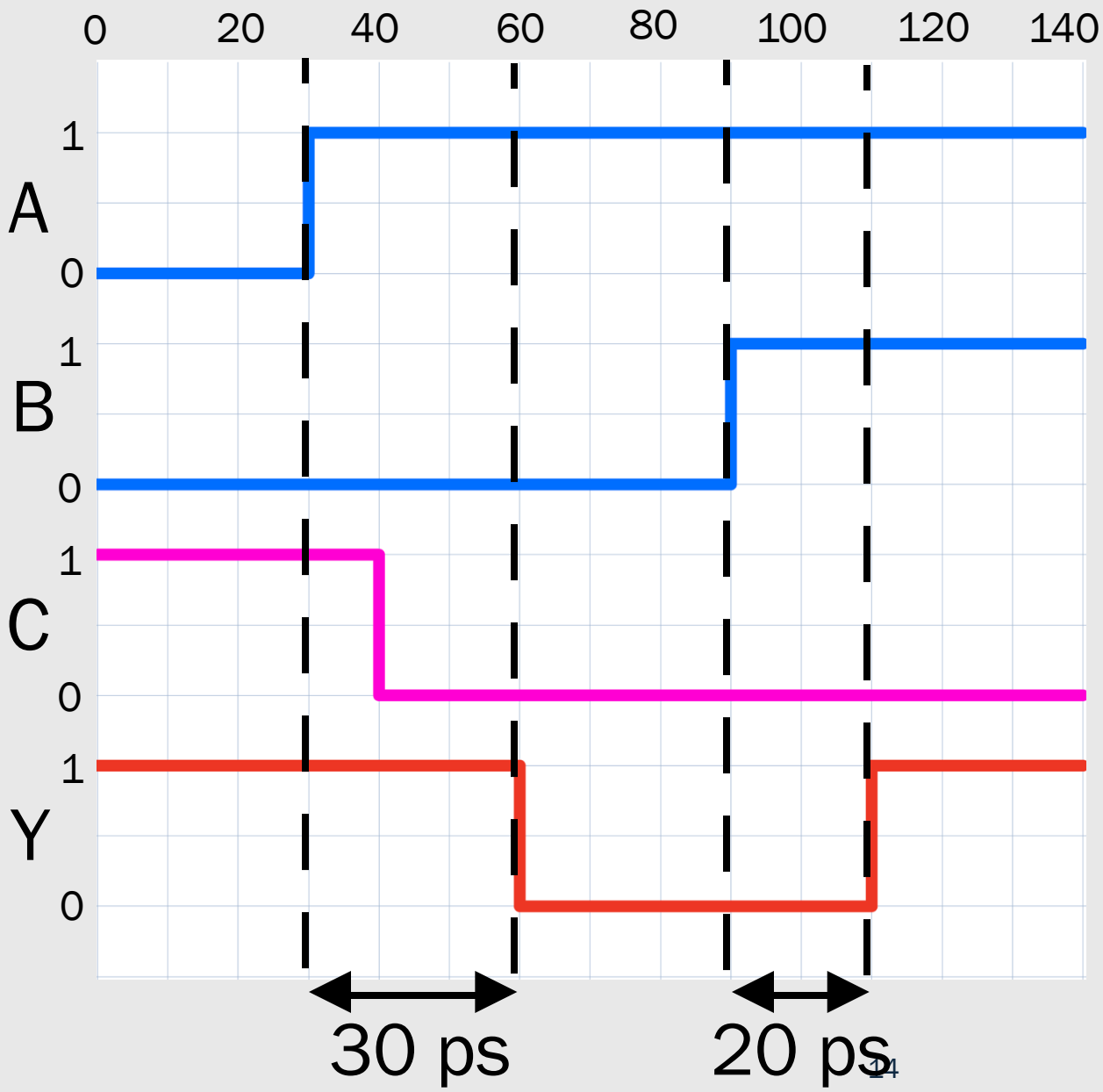
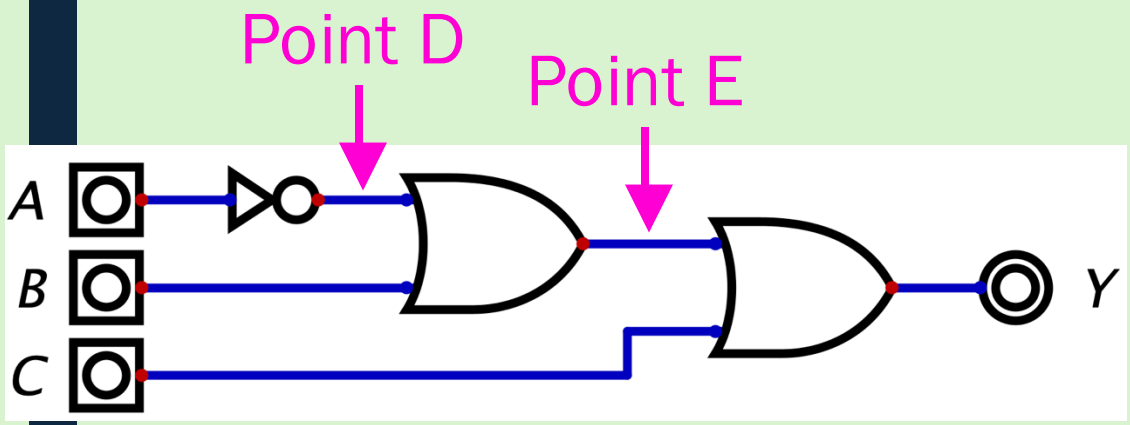
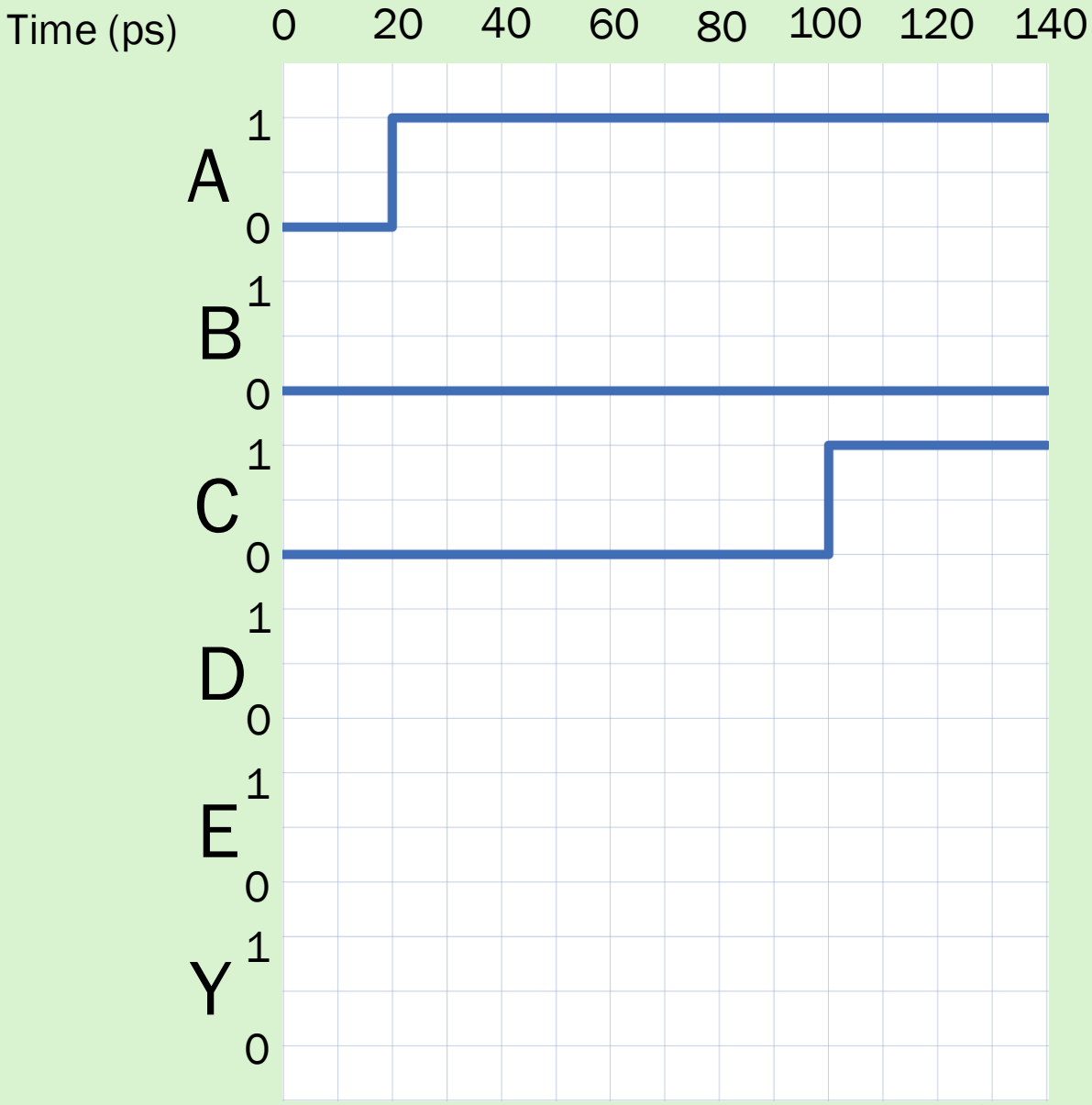


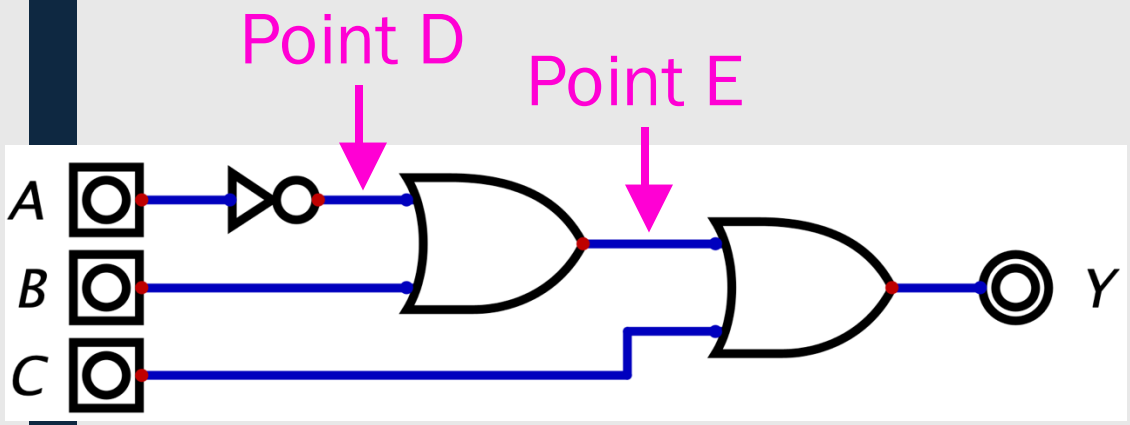
Waveform Diagram with Propagation Delay



Gate	t_{pd} (ps)
NOT	10
OR	30



Waveform Diagram with Propagation Delay



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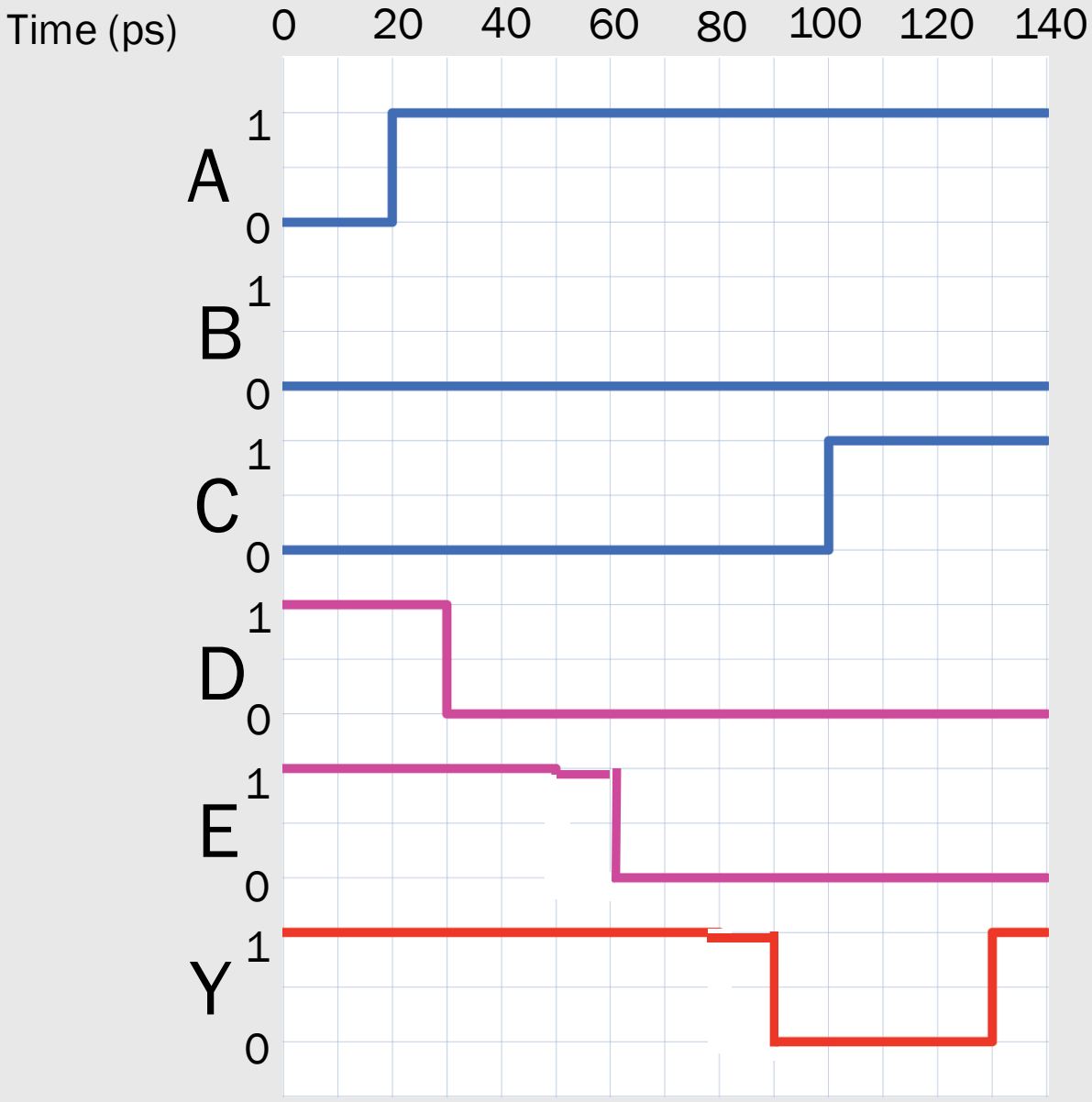


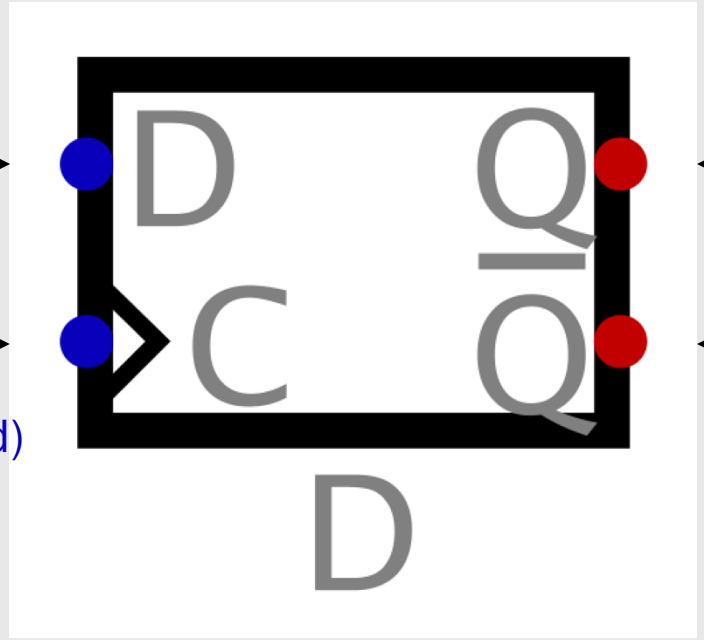
FLIP FLOPS AND REGISTERS

D Flip-Flop

Value to store

Clock

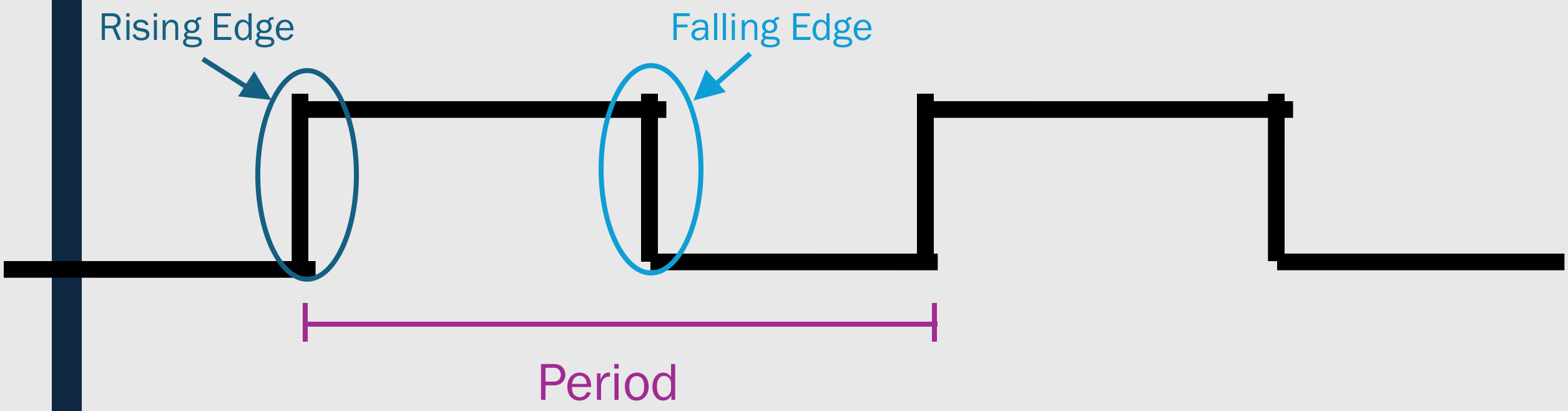
(Determines when D is stored)



Stored Value

Inverted Stored Value

Clock

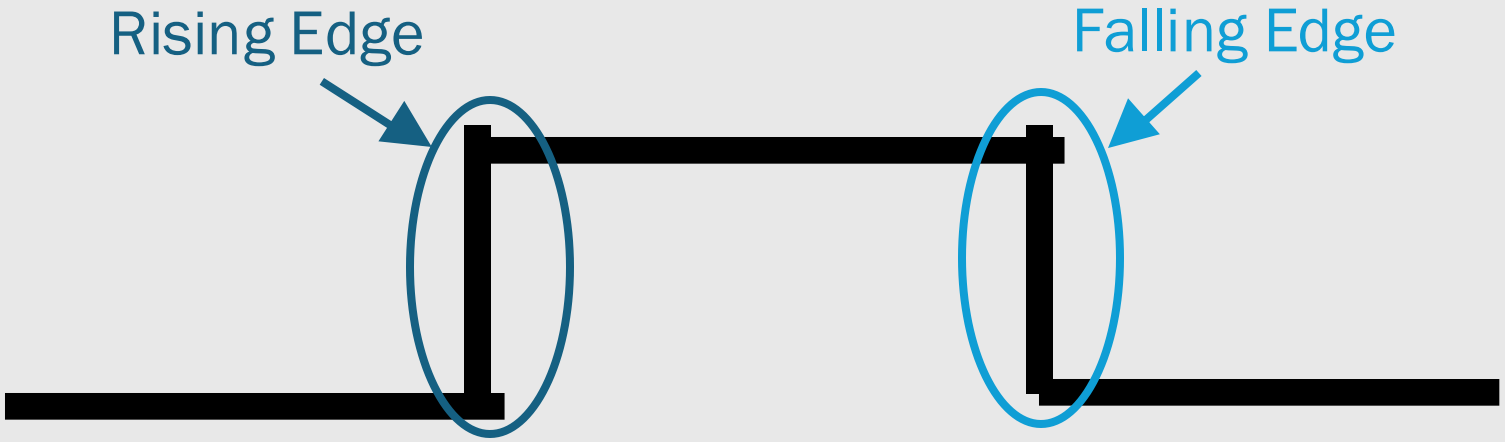


Clock

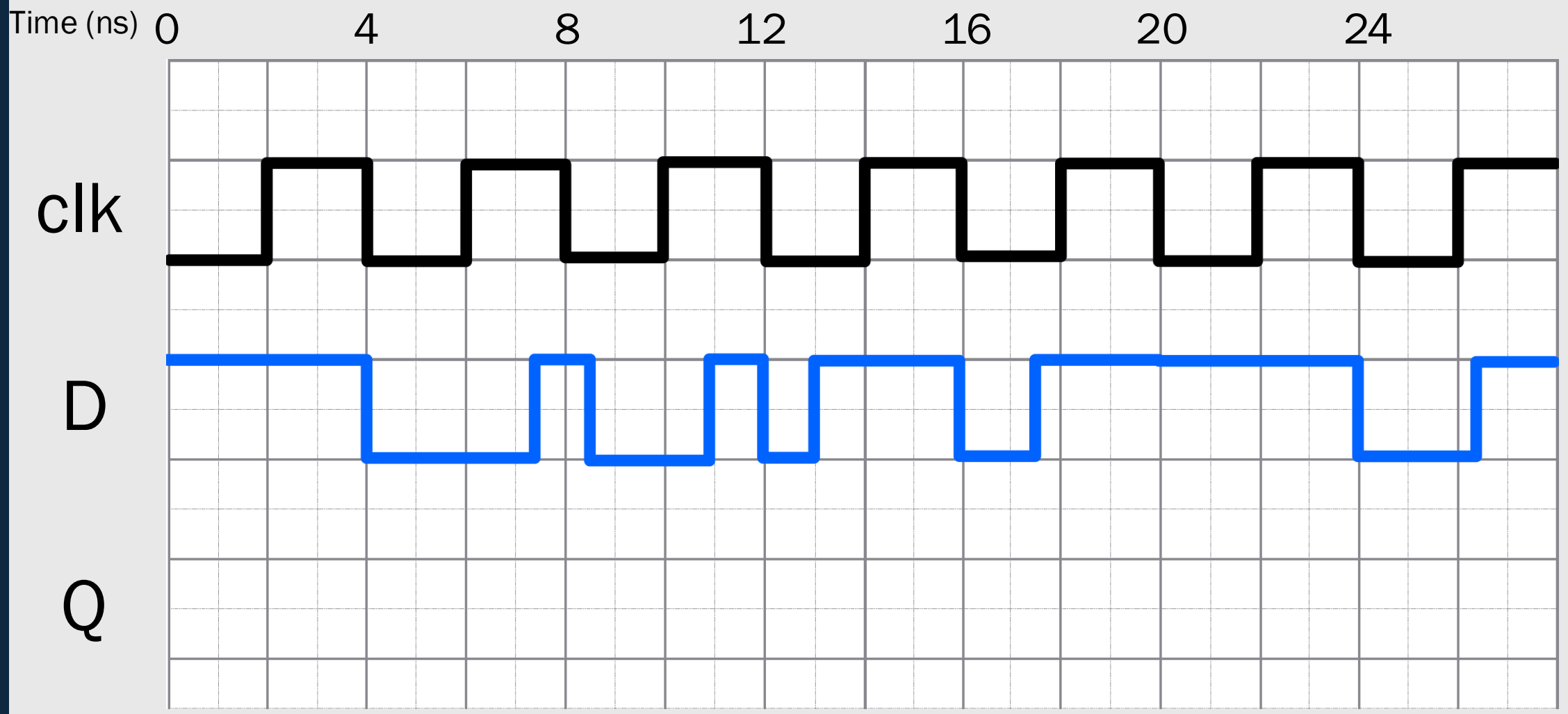
- The clock is a one-bit signal that oscillates (or toggles) back and forth between 0 and 1
- The purpose of the clock is to ensure that our circuits stay in sync
- The period of the clock is the time between one rising edge to the next. The clock spends an equal time in low and high states.
  - *The period determines how fast our circuit runs*
  - *The shorter the period – or in other words the higher the frequency – the faster our circuit will run*

D Flip-Flop

- Positive-edge triggered
  - *Stores D when the clock goes from 0 to 1*
- Negative-edge triggered
  - *Stores D when the clock goes from 1 to 0*

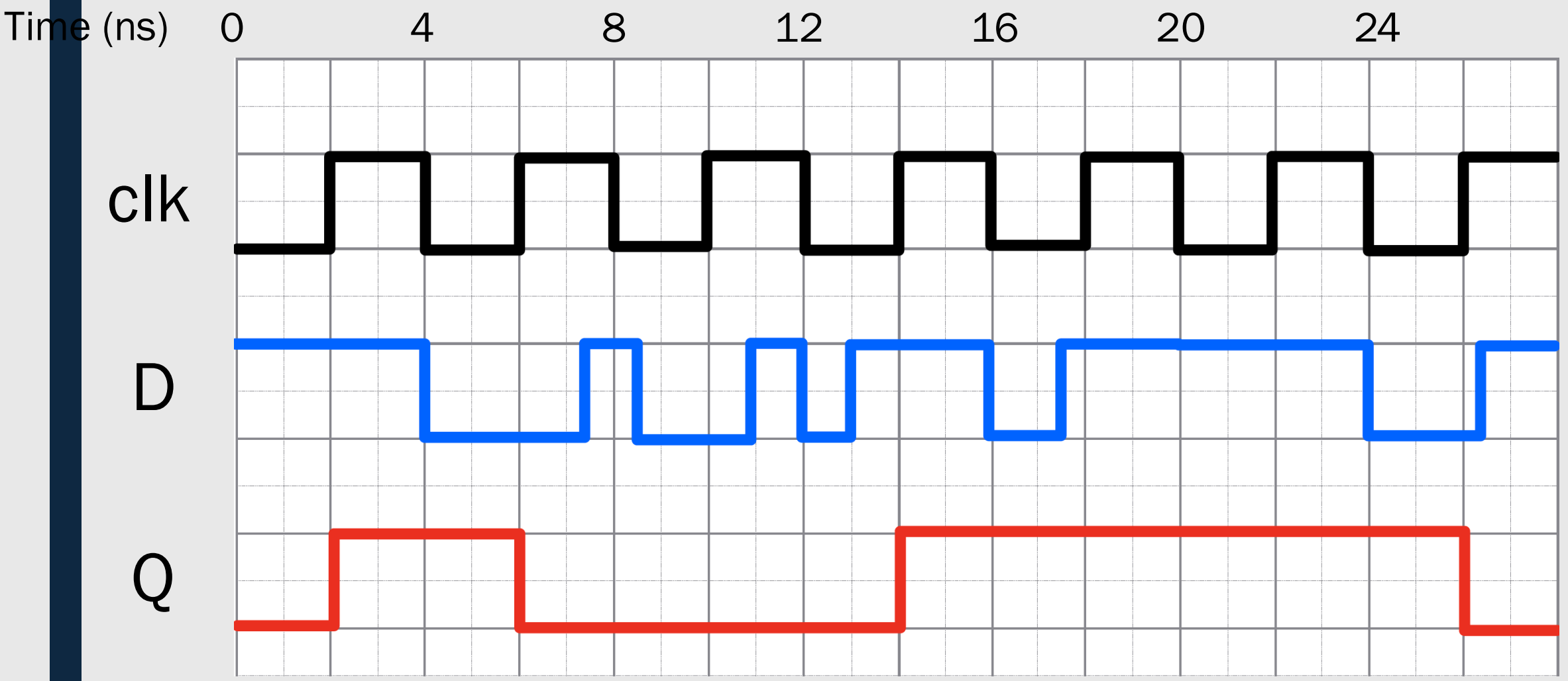


Positive Edge Triggered D Flip-Flop Waveform Diagram



assume Q starts at 0

Positive Edge Triggered D Flip-Flop Waveform Diagram



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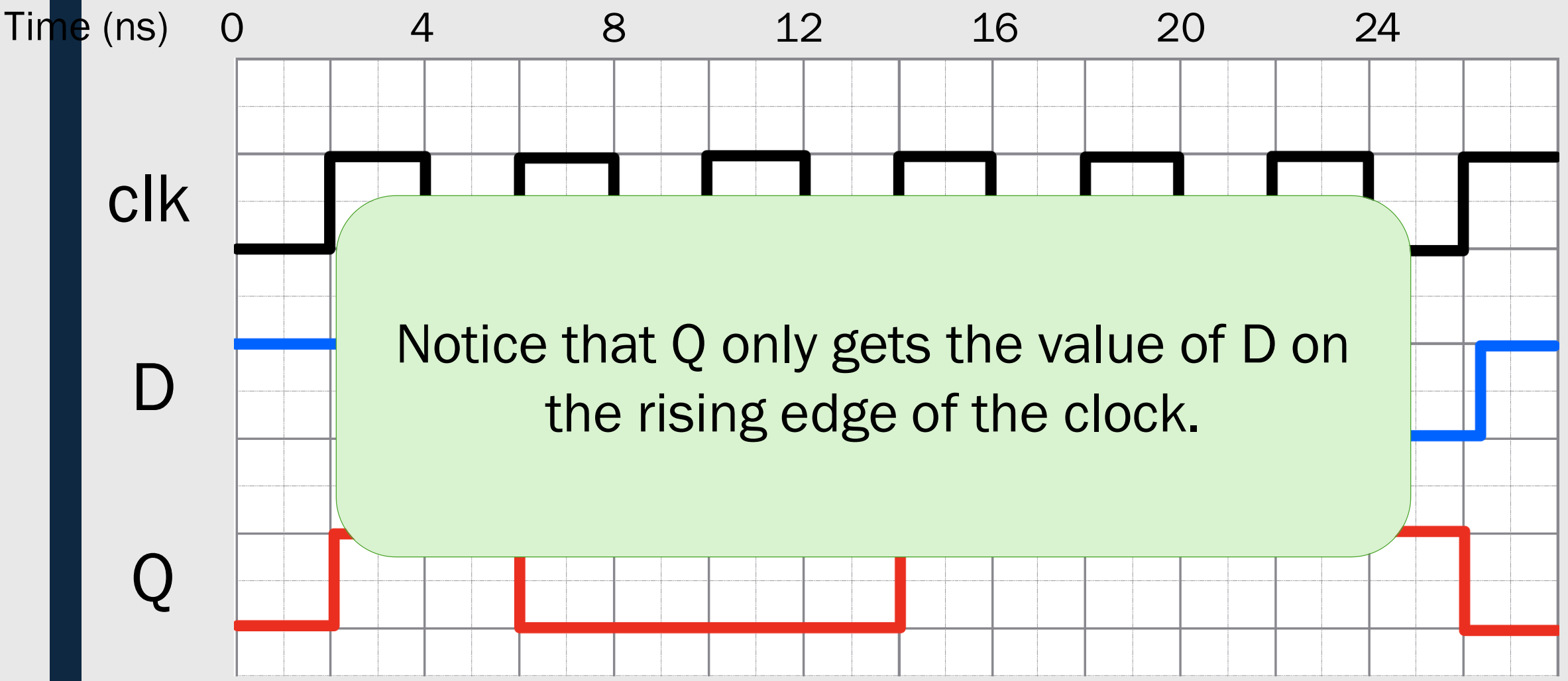
Positive Edge Triggered D Flip-Flop Waveform Diagram



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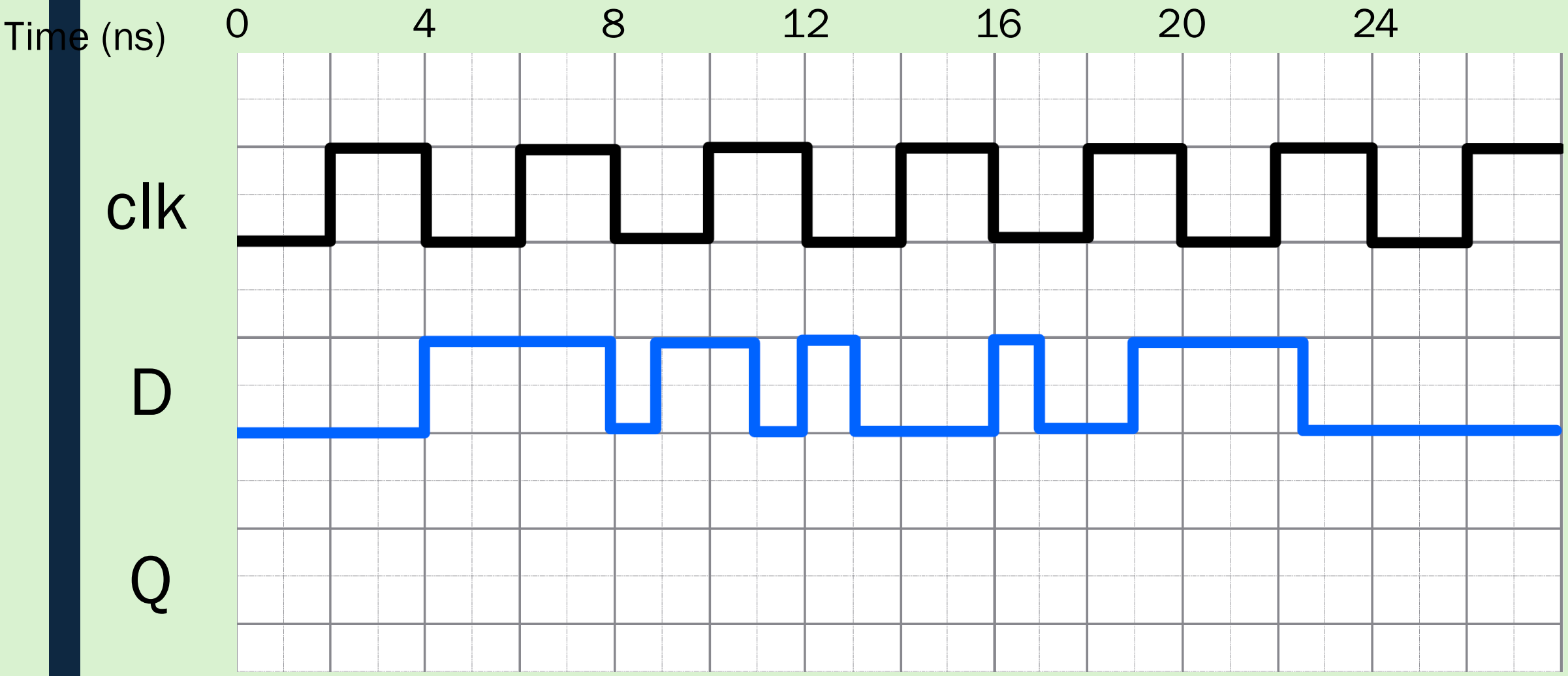

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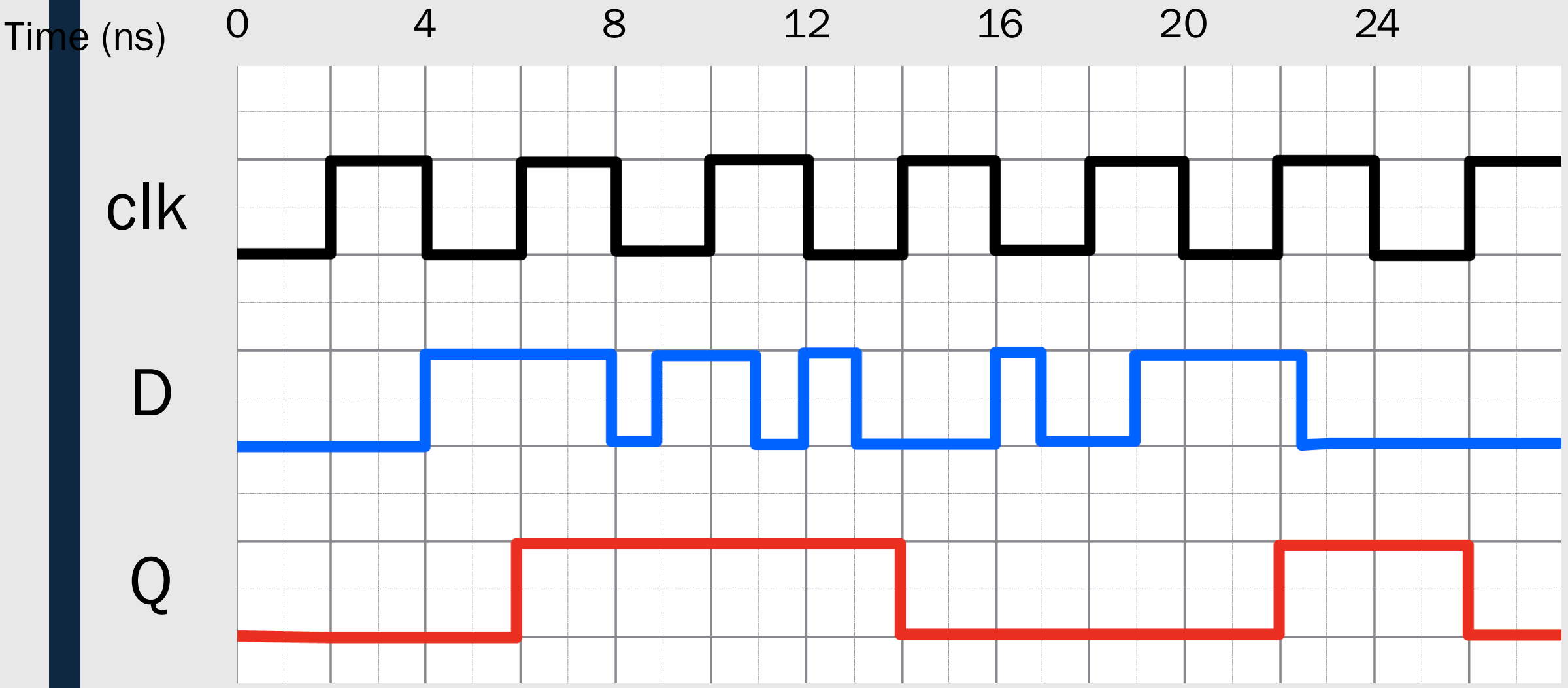

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