Warmup

You are asked organize the **Boston Marathons**, which this year will be **five separate races** on the same course.

In each race, the fastest runner will take at least **2 hours**, and the slowest runner will finish in **5 hours or less**.

Multiple races can use the course at once, but everyone from one race must finish before racers from the next race can finish.

It takes **10 minutes to reset** the finish line after the last runner crosses from each race.

How long will it take for all five races to finish?

Besides making people run faster, **how can you speed it up**?

ES 4: Timing combinational logic

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By the end of class today, you should be able to:

- Given a circuit and timing information about the gates, calculate the contamination delay and propagation delay
- Optimize a circuit for speed
- Explain what glitches are and why they occur

Timing

Depends on lots of things!

(excerpts from SN74LS04 datasheet)

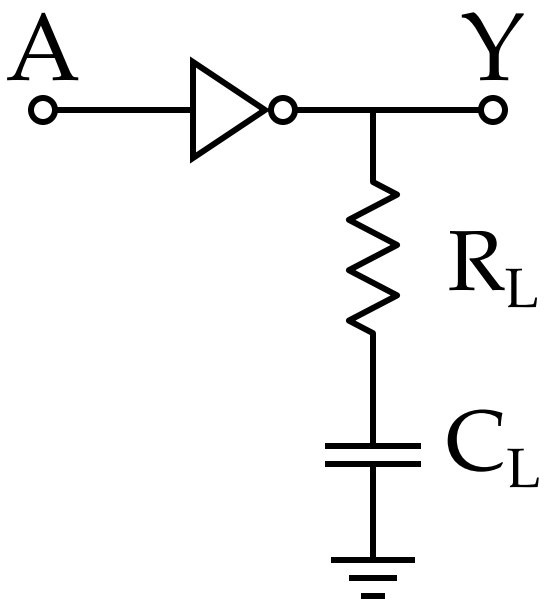
switching characteristics, V_{CC} = 5 V, T_A = 25◦C (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	SN5404 SN7404			UNIT
				MIN	TYP	MAX	
t_{PLH}	A	Y	R_L = 400 Ω, C_L = 15 pF		12	22	ns
t_{PHL}					8	15	

switching characteristics, V_{CC} = 5 V, T_A = 25◦C (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	SN54S04 SN74S04			UNIT
				MIN	TYP	MAX	
t_{PLH}	A	Y	R_L = 280 Ω, C_L = 15 pF		3	4.5	ns
t_{PHL}					3	5	
t_{PLH}	A	Y	R_L = 280 Ω, C_L = 50 pF		4.5		ns
t_{PHL}					5		

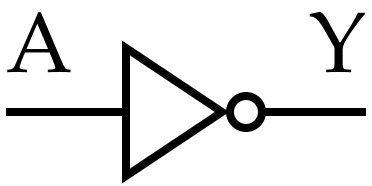
Timing



Timing

Contamination delay: the soonest that the output might change

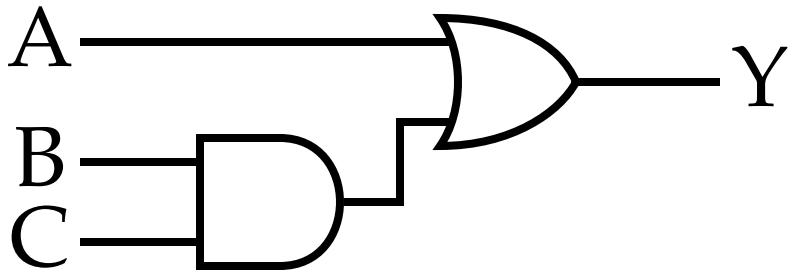
Propagation delay: the maximum time for the output to settle



Timing practice

Find the contamination delay and propagation delay for this circuit

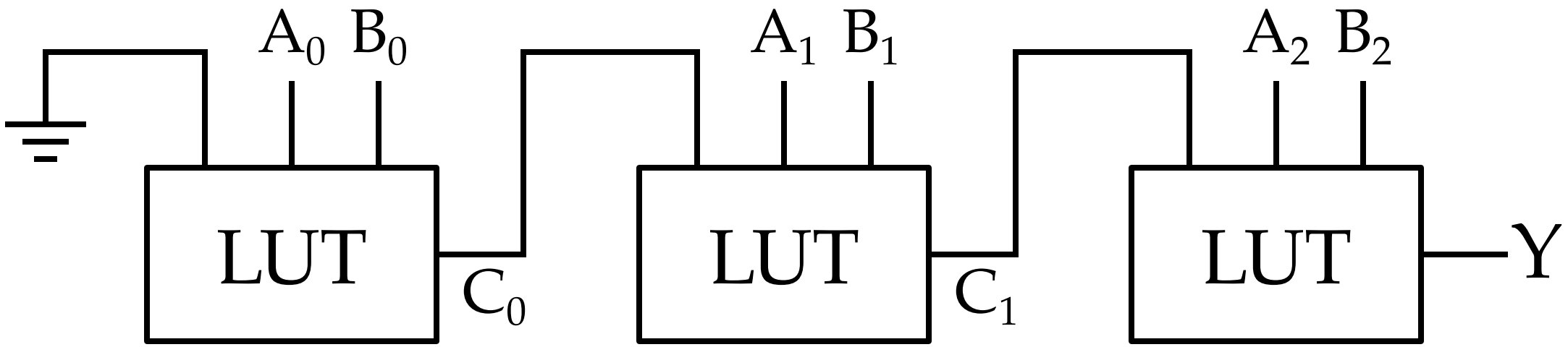
Gate	t_{pd} (ps)	t_{cd} (ps)
NOT	15	10
2-input NAND	20	15
3-input NAND	30	25
2-input NOR	30	25
3-input NOR	45	35
2-input AND	30	25
3-input AND	40	30
2-input OR	40	30
3-input OR	55	45
2-input XOR	60	40



Timing practice

Find the propagation delay for this circuit

Assume the LUT has a delay of 10ns from input (A/B) to output (C/Y)

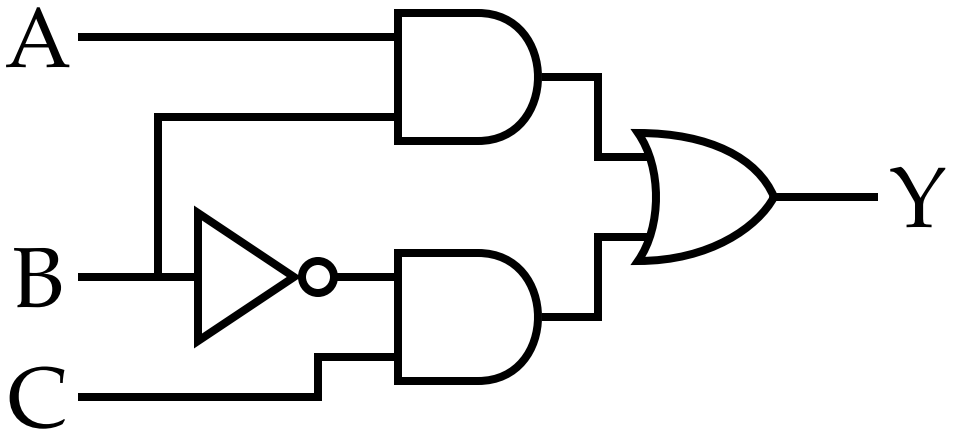


Who cares?

t_{cd} and t_{pd} combine to determine how fast the circuit can run.

Show and tell

Glitches




digital design
POWER TOOLS!

For Monday

1. Read the book (4.1-4.2) and complete the pre-class quiz

2. Homework is due on Monday (2/11)

3. Lab 2 is next week; prelab due on Gradescope 24 hours in advance