CSSE2010

CSSE2010/CSSE7201
Lecture 4

Combinational Logic

School of Information Technology and Electrical Engineering
The University of Queensland

Today…

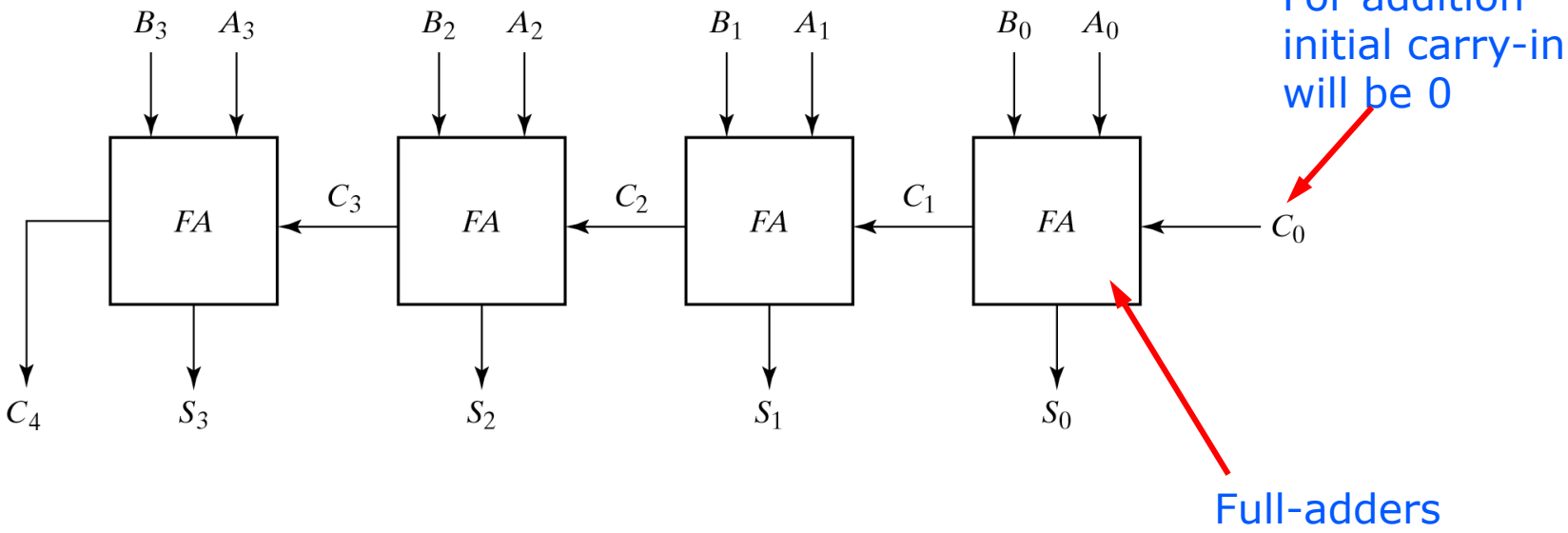
- Admin
- Binary Subtractors
- More Combinational Logic Circuits
  - Multiplexers
  - Decoders
  - Timing diagram representations

Admin

- Quiz 1 due on Friday 4pm – no extensions for quizzes
- Lab 4 preparation task – next week (week 3)
  - Will be Available on Blackboard: Learning Resources
  - Draw some circuit schematic diagrams
  - Bring to Lab 4 (Mon-Tue next week)
  - IN students – use Logic ICs on breadboards or Logisim
  - EX students – use Logisim software to simulate
- Supporting material for labs are now on Blackboard

Recall – Binary Adder

- Can cascade full adders to make binary adder
  - Example: for 4 bits…



- This is a **ripple-carry adder**

[Figure from Mano, "Digital Design", 3rd edition]

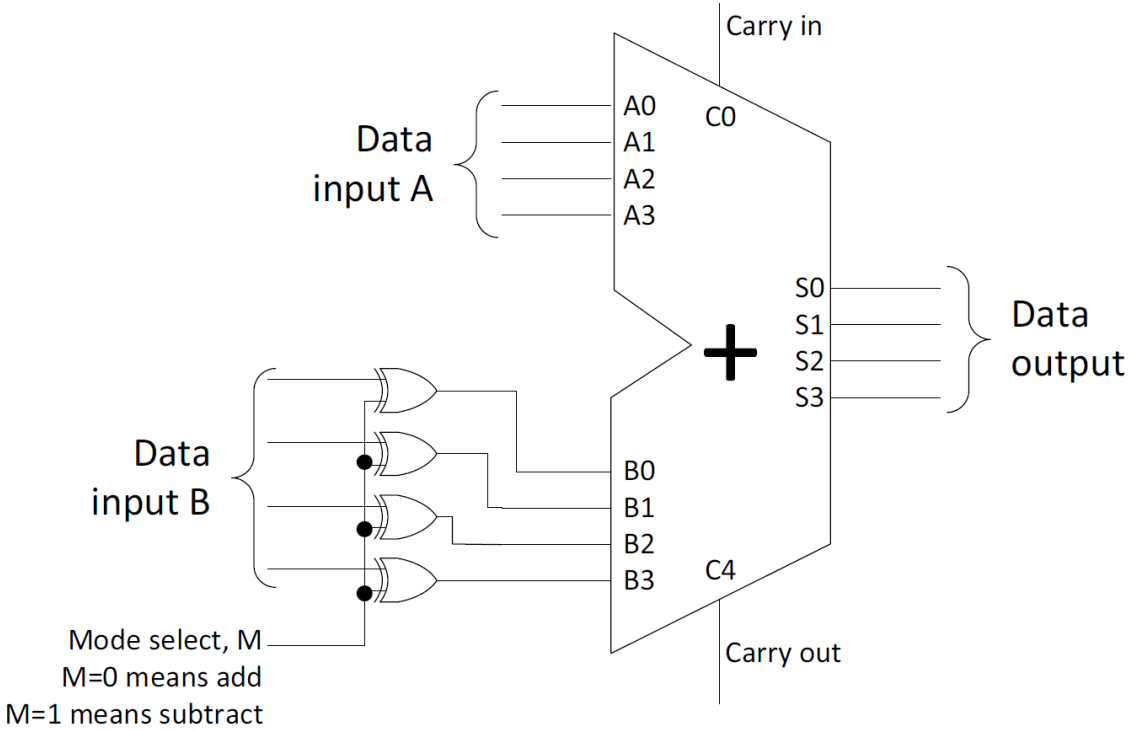
Binary subtraction

- A-B - usually implemented as A+(-B)
  - A and B are multi-bit quantities
  - "+" in this case means addition (not OR)
  - -B means negative B – the two's complement of B
- Two's complement of B can be calculated by flipping bits and adding 1

Binary subtraction (cont.)

- How we can use a gate to flip a bit – but only sometimes? i.e.
  - Z=not(B) when M is 1
    Z=B when M is 0

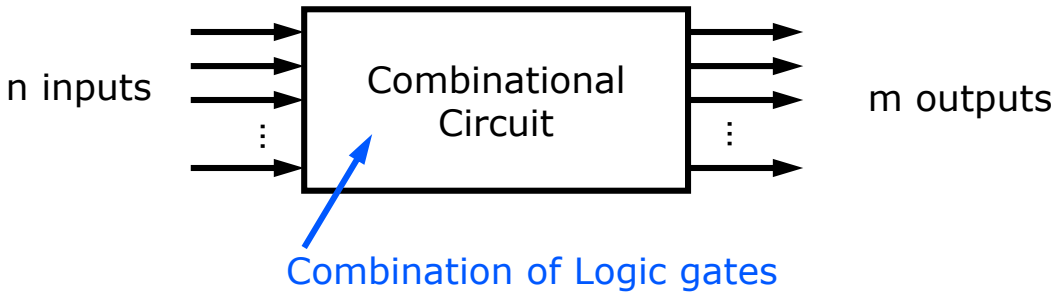
Adder-subtractor



- What should carry-in be?

Combinational Circuits

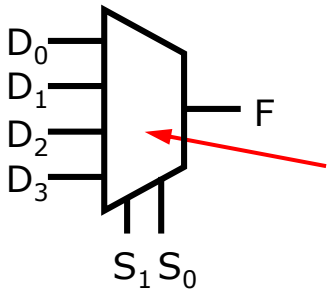
- Generally,



- Each output can be expressed as function of n input variables
- Output depends on current inputs only
- Can write truth table also:
  - n input columns
  - m output columns
  - 2^n rows (i.e. possible input combinations)

Multiplexer (or Mux)

- 2^n data inputs
- 1 output
- n control (or ***select***) inputs – that *select* one of the inputs to be "sent" or "steered" to the output
- Example: 4-to-1 multiplexer



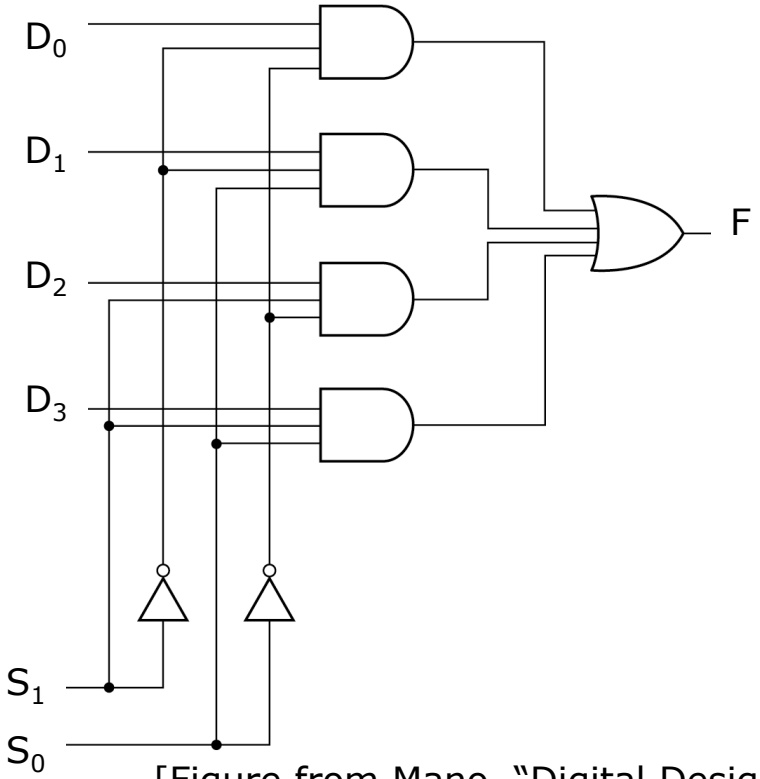
Logic symbol for multiplexer

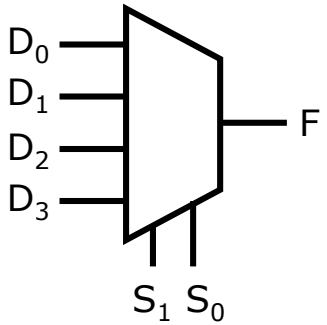
Function table

S_1	S_0	F
0	0	D_0
0	1	D_1
1	0	D_2
1	1	D_3

"Select" inputs

4-to-1 Multiplexer Logic Circuit Implementation

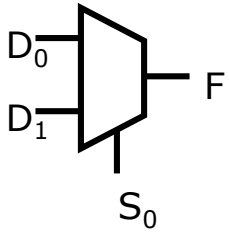




[Figure from Mano, "Digital Design", 3rd edition]

Clicker Question: 2-to-1 Multiplexer

- Consider a 2-to-1 multiplexer
  - Data Inputs: D_0 and D_1
  - Control Input: S_0
  - Output: F
- What is the truth table that goes with this circuit?



Function Table

S_0	F
0	D_0
1	D_1

1.

S_0	D_0	D_1	F
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

2.

S_0	D_0	D_1	F
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

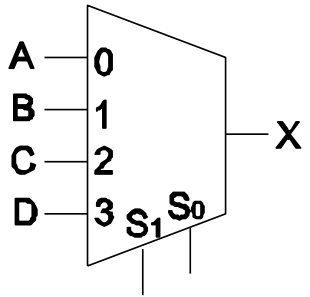
3.

S_0	D_0	D_1	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

Clicker Question (2)

Consider the multiplexer shown. What must the inputs A,B,C,D be so that the multiplexer output is

$$X = \overline{S_0} + S_1$$



0% 1. A=0, B=1, C=0, D=0

0% 2. A=0, B=1, C=1, D=1

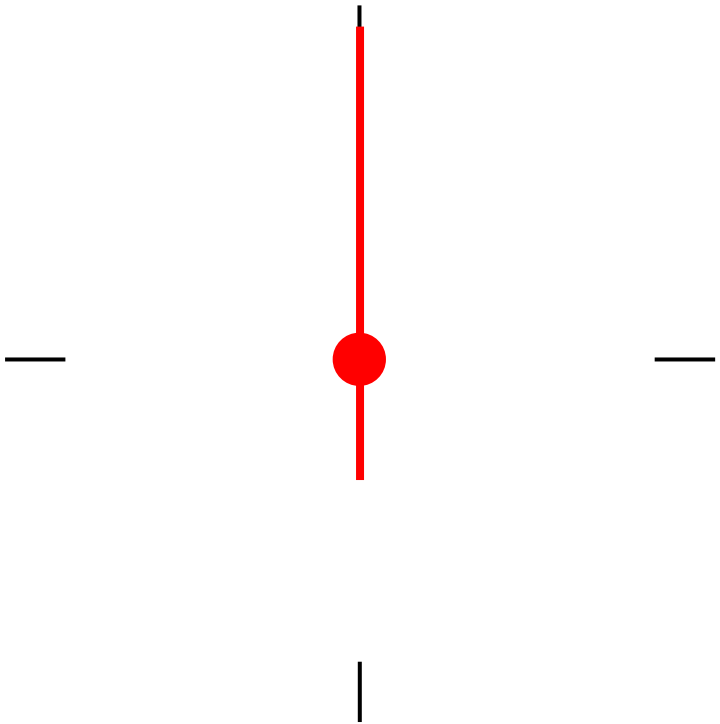
0% 3. A=1, B=0, C=1, D=1

0% 4. A=1, B=1, C=0, D=1

10

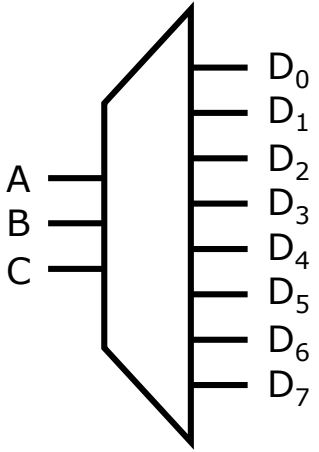
Short Break

- Stand up and stretch



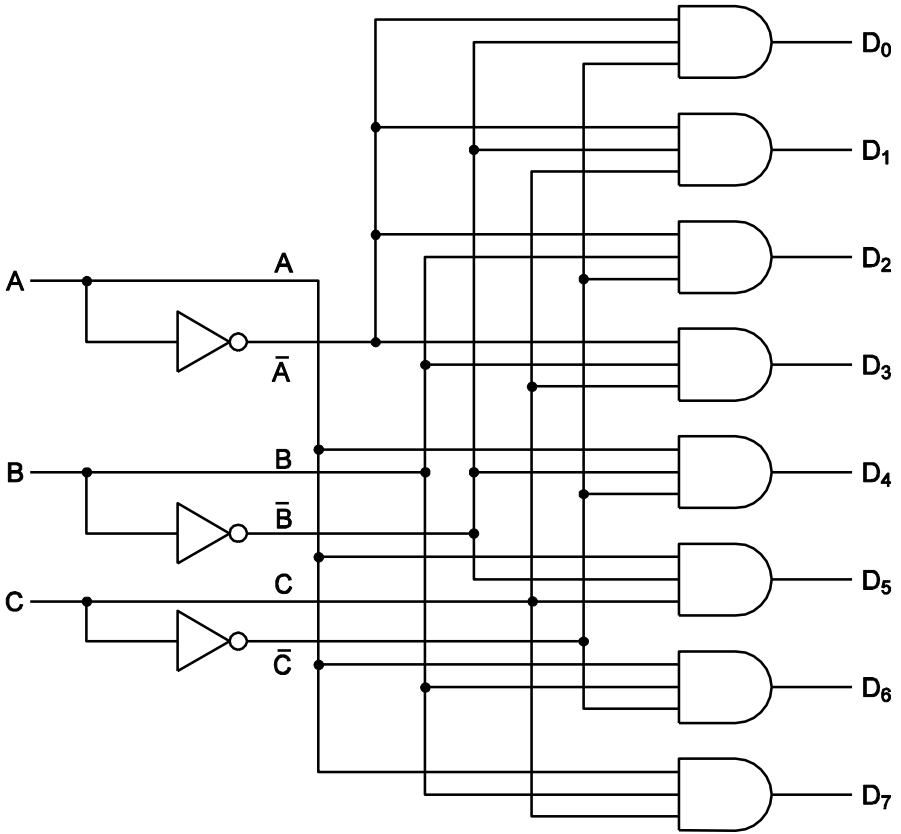
Decoder

- Converts n-bit input to a logic-1 on exactly one of 2^n outputs
- Example:
  3-to-8 decoder



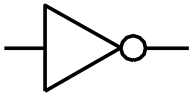
A	B	C	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
0	0	0	**1**	0	0	0	0	0	0	0
0	0	1	0	**1**	0	0	0	0	0	0
0	1	0	0	0	**1**	0	0	0	0	0
0	1	1	0	0	0	**1**	0	0	0	0
…	…	…	…	…	…	…	…	…	…	…

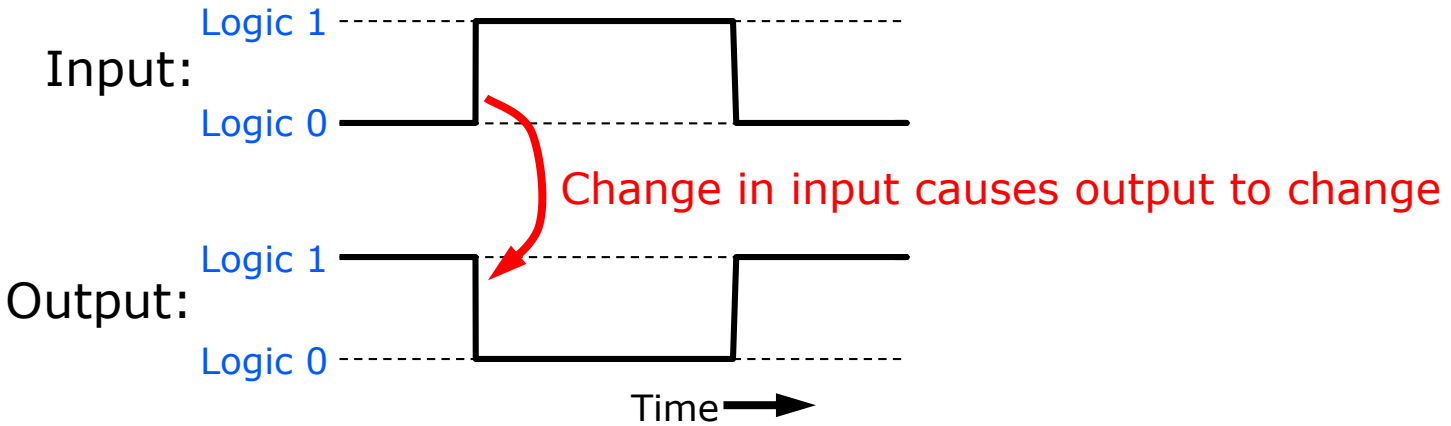
3-to-8 Decoder
Logic Circuit Implementation



Another Logic Representation: Timing Diagram

- Consider an inverter

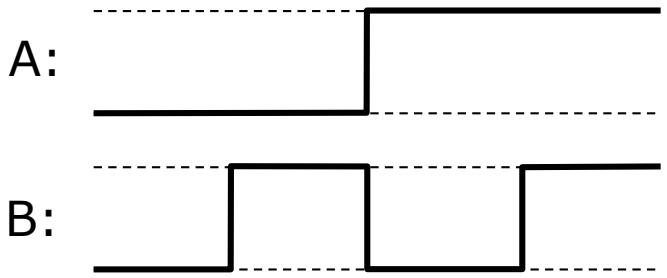




- Like a truth table, but graphical format
  - Input waveforms show all possible combinations

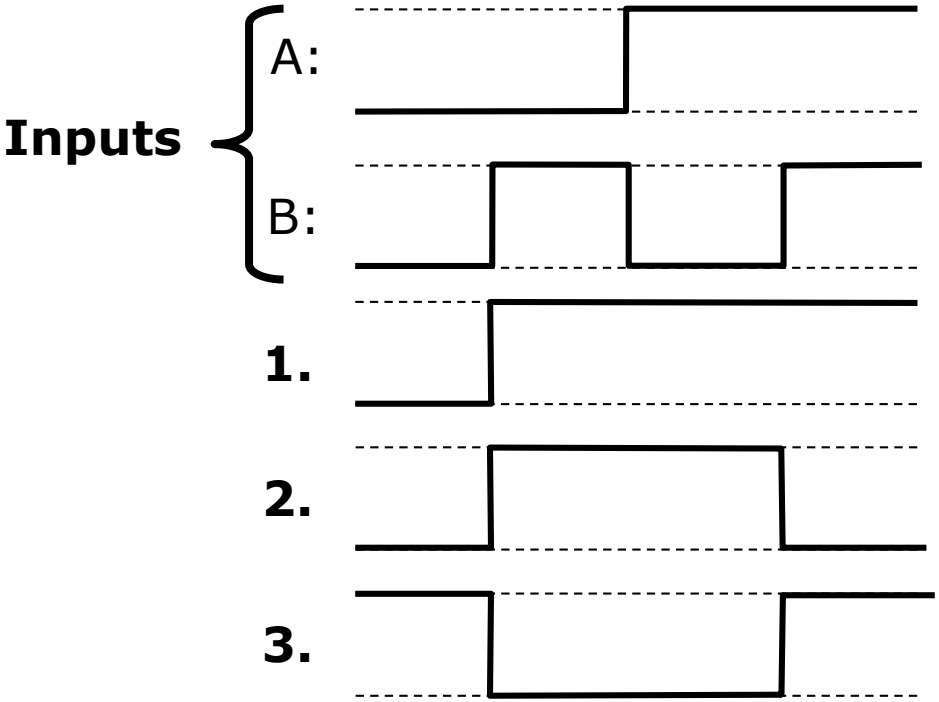
Consider a 2-input gate

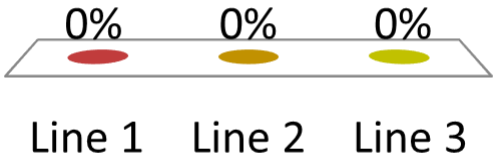
- Possible inputs



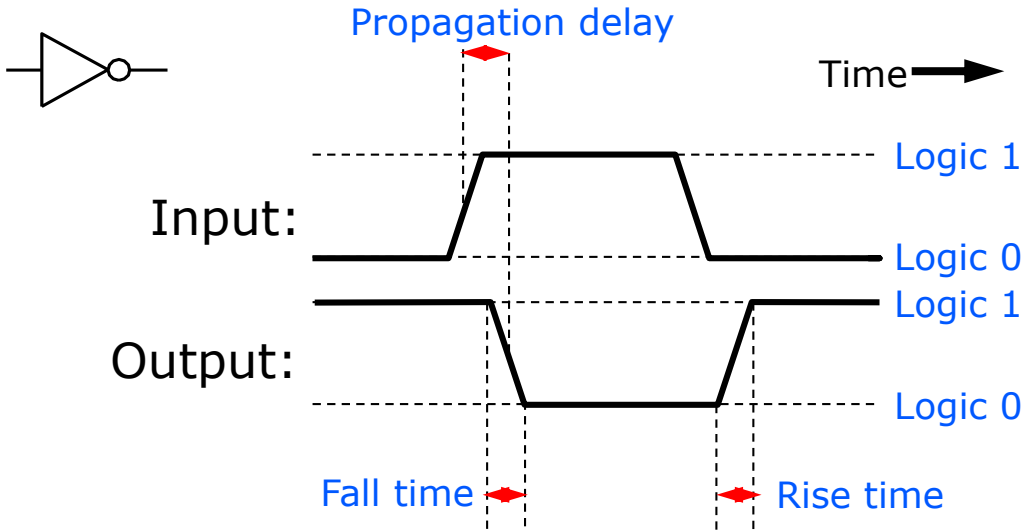
- All combinations of inputs are covered

Which of the following is a timing diagram representation for an XOR gate?





Gates Aren't Perfect ... The Reality of Timing



- **Propagation delay** – time for change in input to affect output
- **Fall time** – time taken for output to fall from 1 to 0
- **Rise time** – time for output to rise from 0 to 1

Things To Do

- Complete quiz 1 by Friday 4pm this week
- Homework – Lab 4 preparation
  - By Lab 4 sessions on week 3
- Attempt the posted exercises and self-check questions
- Any doubts, use course consultation (need to book a time) or ask after the lecture.