Logic Circuits II

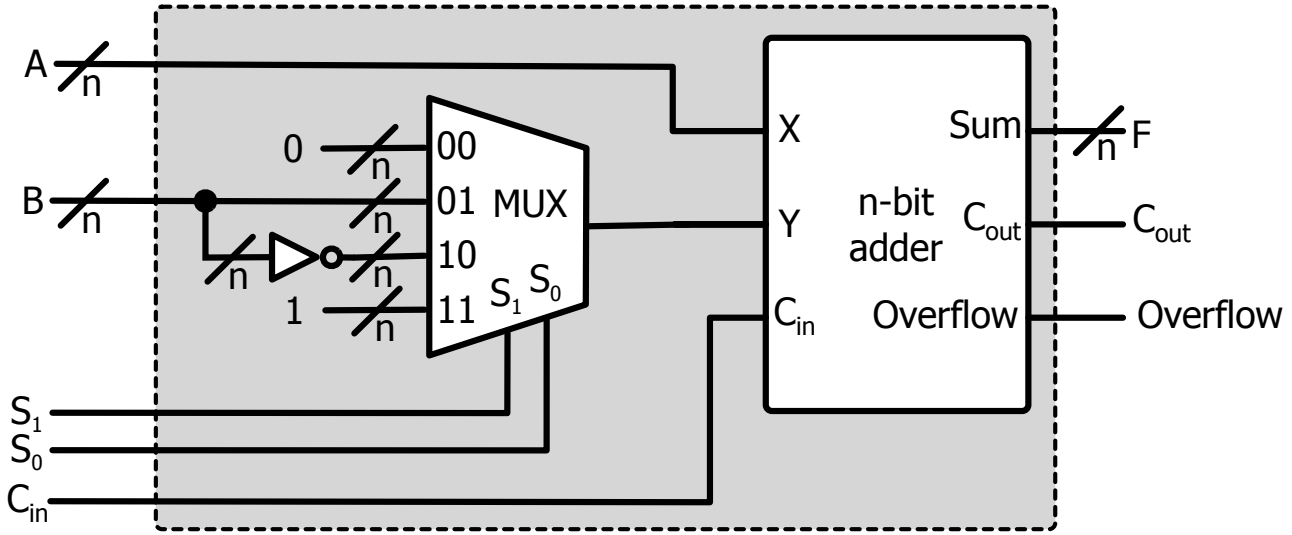
010.133
Digital Computer Concept and Practice
Spring 2013

Lecture 04

Arithmetic Unit

- Integer addition and subtraction
- Two's complement representation

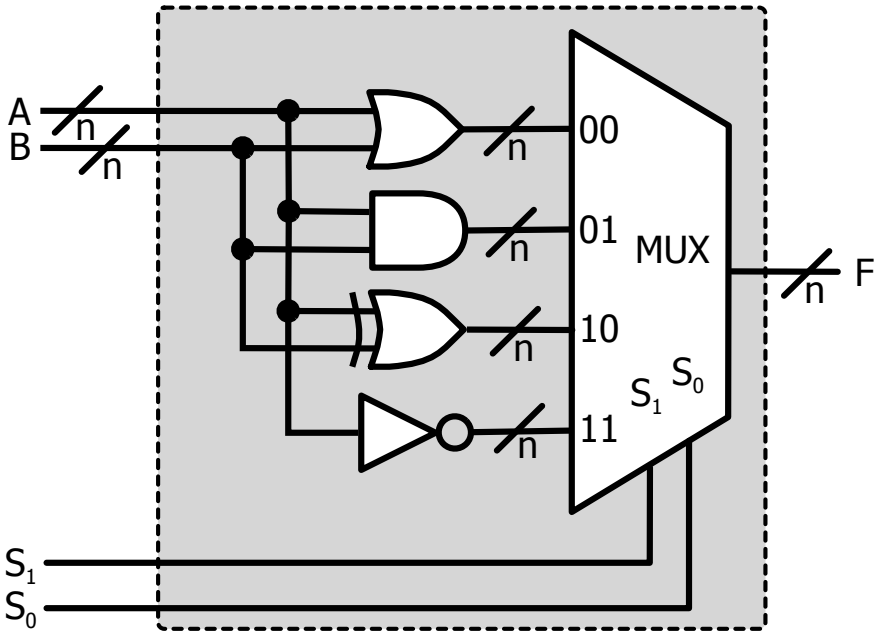
S_1	S_0	Y	C_{in} = 0	C_{in} = 1
0	0	00⋯0	F = A	F = A+1
0	1	B	F = A+B	F = A+B+1
1	0	B′	F = A+B′	F = A+B′+1
1	1	11⋯1	F = A-1	F = A



Logic Unit

- Bitwise OR, AND, XOR, and NOT

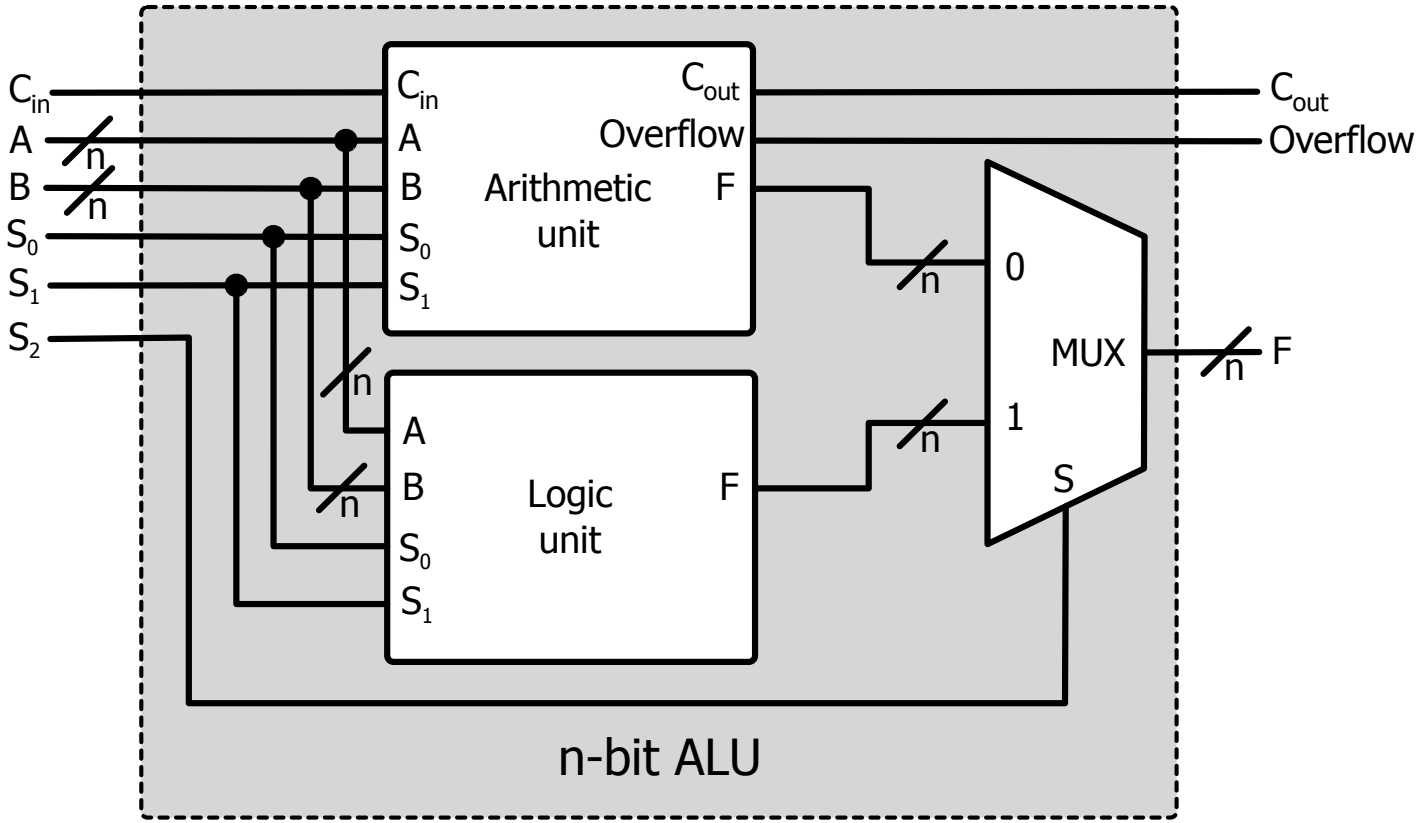
S_1	S_0	output	operation
0	0	F = A ∨ B	OR
0	1	F = A ∧ B	AND
1	0	F = A ⊕ B	XOR
1	1	F = A′	NOT



ALU

- Arithmetic unit + logic unit

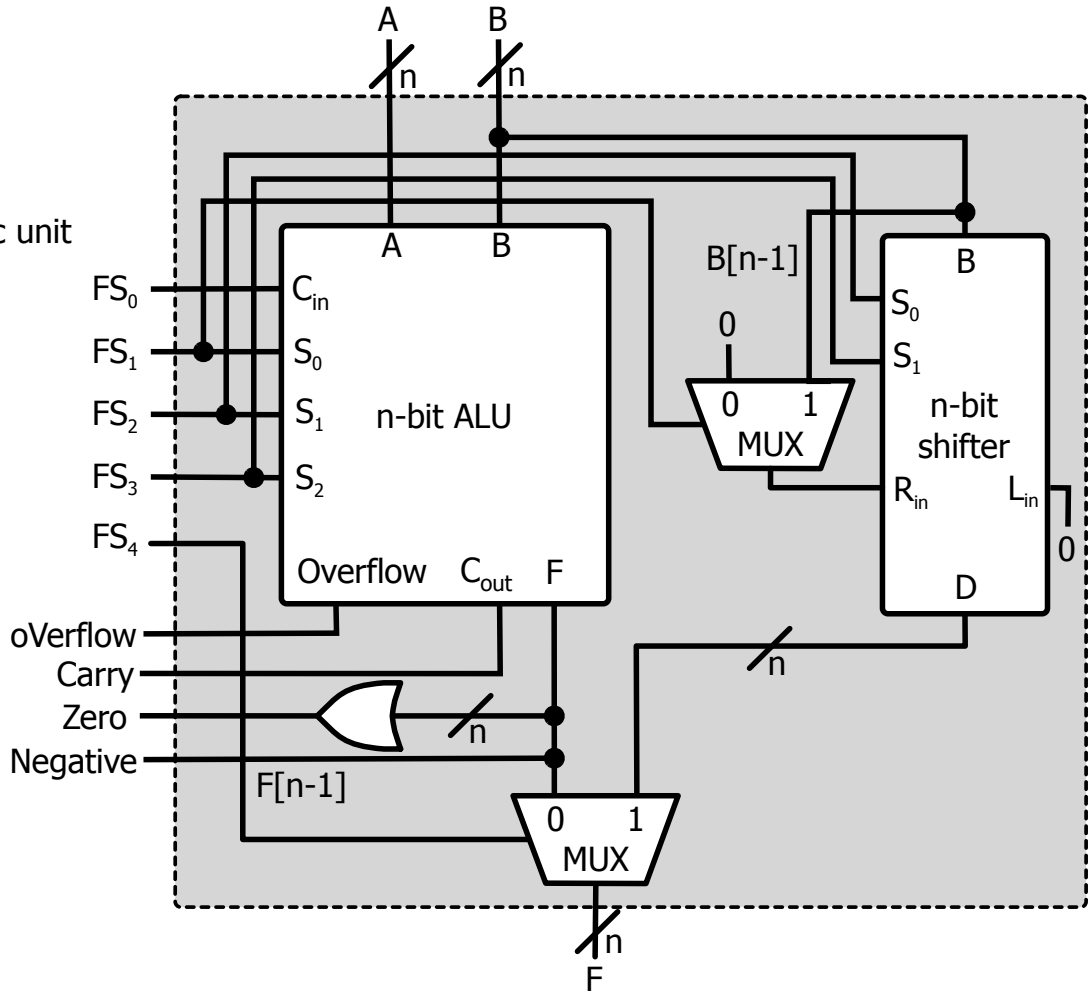
S_2	S_1	S_0	C_{in}	Operation
0	0	0	0	F = A
0	0	0	1	F = A+1
0	0	1	0	F = A+B
0	0	1	1	F = A+B+1
0	1	0	0	F = A+B′
0	1	0	1	F = A+B′+1
0	1	1	0	F = A-1
0	1	1	1	F = A
1	0	0	X	F = A∨B
1	0	1	X	F = A∧B
1	1	0	X	F = A⊕B
1	1	1	X	F = A′



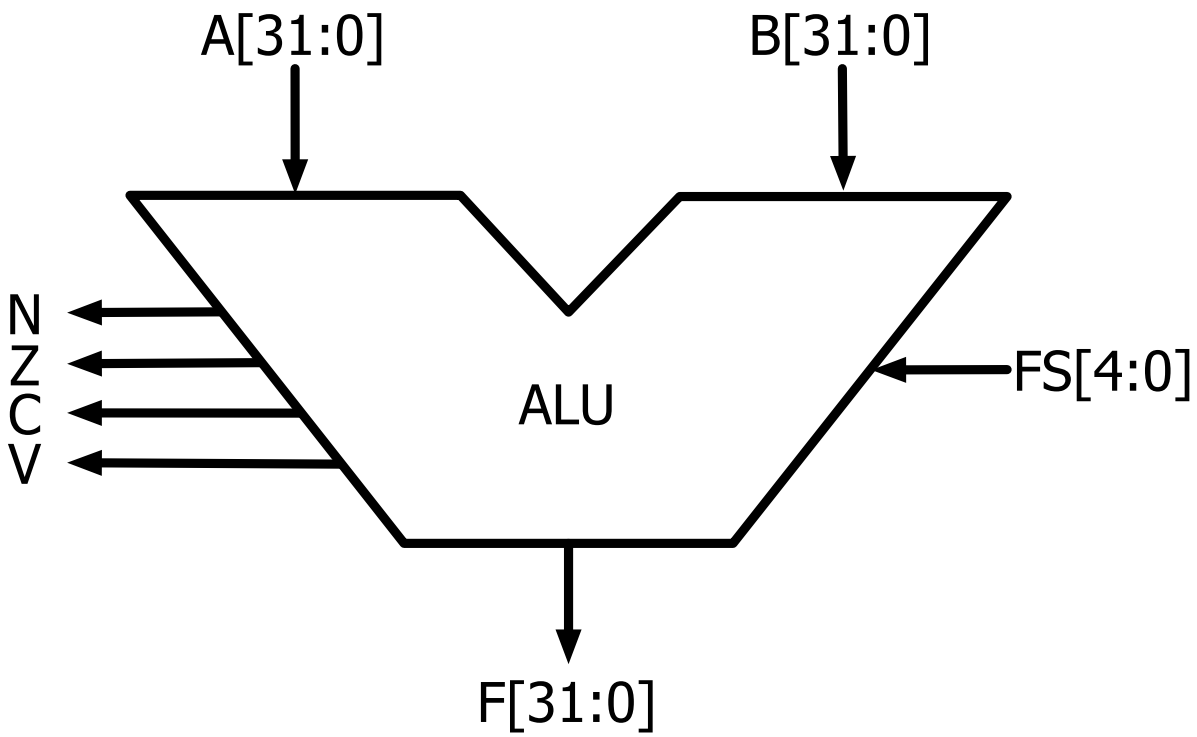
ALU in a Broader Sense

- ALU + shifter

FS_4	FS_3	FS_2	FS_1	FS_0	Operation	
0	0	0	0	0	F = A	Arithmetic unit
0	0	0	0	1	F = A+1	
0	0	0	1	0	F = A+B	
0	0	0	1	1	F = A+B+1	
0	0	1	0	0	F = A+B′	
0	0	1	0	1	F = A+B′+1	
0	0	1	1	0	F = A-1	
0	0	1	1	1	F = A	
0	1	0	0	X	F = A∨B	Logic unit
0	1	0	1	X	F = A∧B	
0	1	1	0	X	F = A⊕B	
0	1	1	1	X	F = A′	
1	0	0	X	X	F = B	Shifter
1	0	1	0	X	F = logical shift right B	
1	0	1	1	X	F = arithmetic shift right B	
1	1	0	X	X	F = shift left B	
1	1	1	X	X	F = B	



ALU Symbol

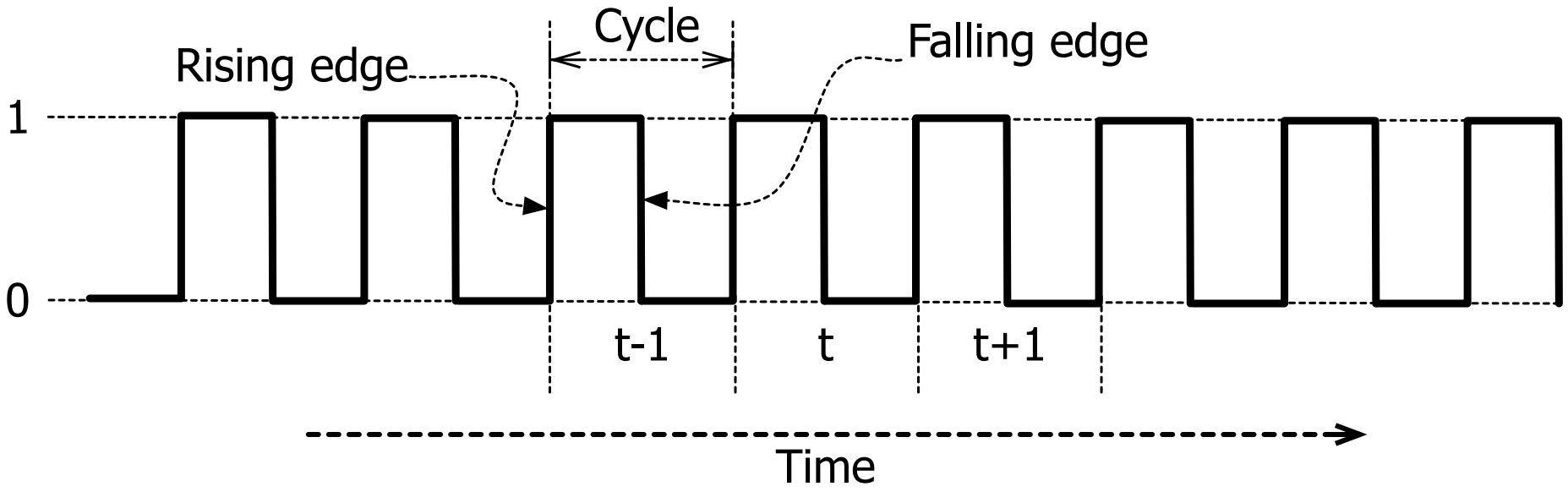


Combinational Logic vs. Sequential Logic

- The outputs of a combinational logic circuit
  - Totally dependent on the current input values and determined by combining the input values using Boolean operations
- The outputs of a sequential logic circuit
  - Depend not only on the current input values but also on the past inputs
    - Logic gates + memory
    - Outputs are a function of the current input values and the data stored in memory
      - A function of time
    - States

Clock

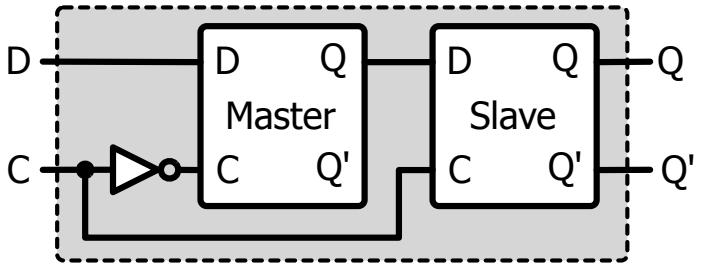
- The clock signal is simultaneously broadcast to every circuit component
- Every operation in the circuit must be completed inside a clock cycle

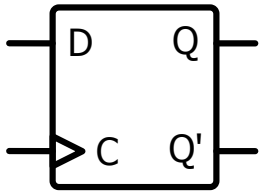


Gate Delay

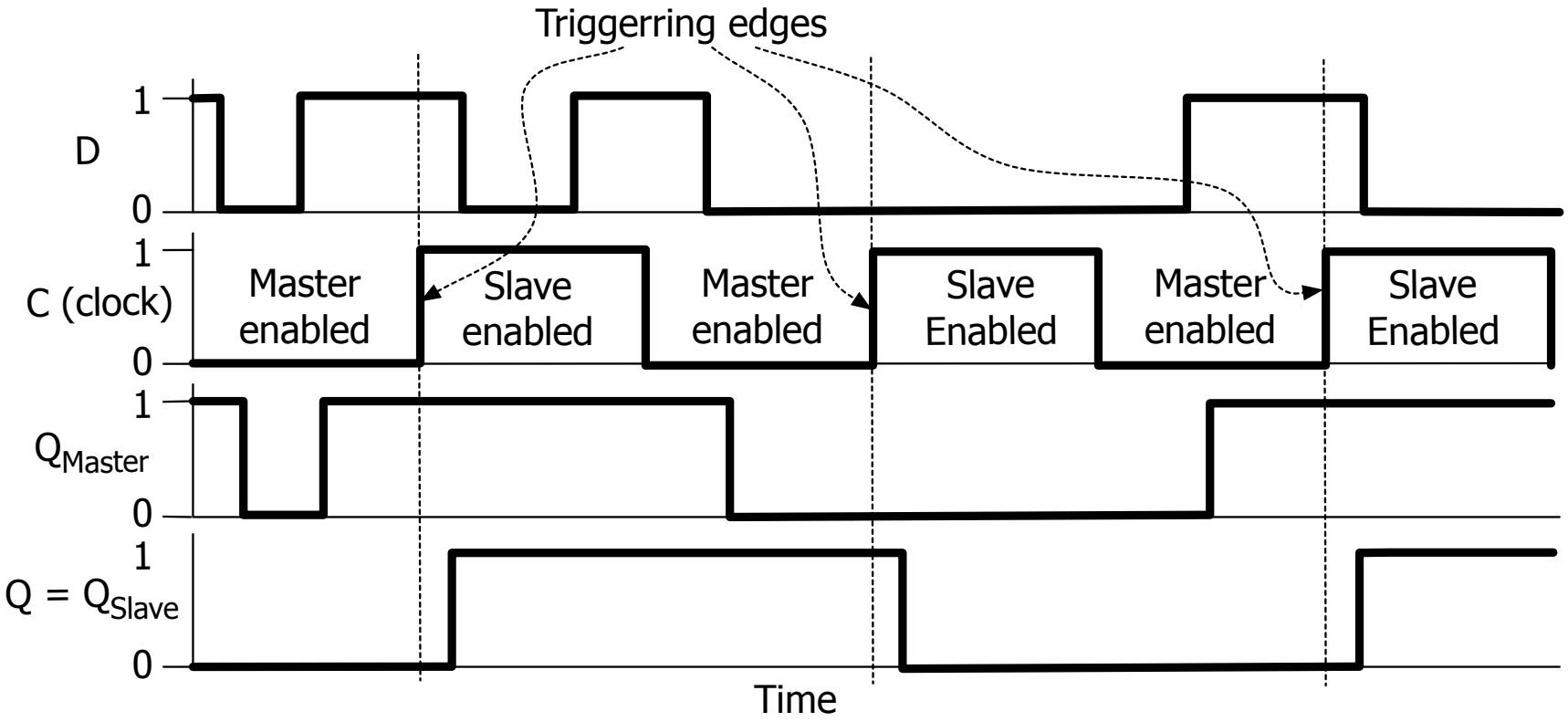
- Also known as propagation delay
- The time delay between the changes when an input change causes an output change

The D Flip-flop



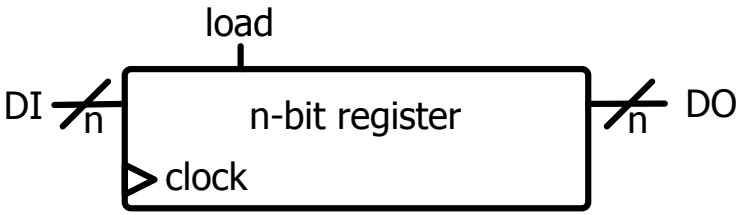


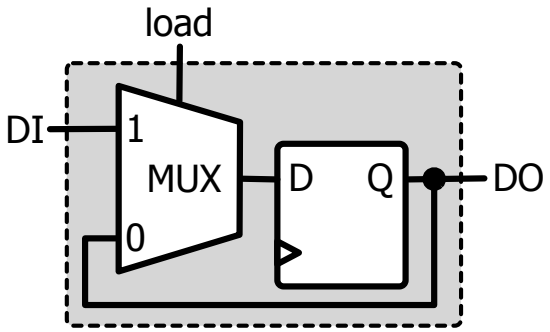
Asynchronous inputs:
preset and clear

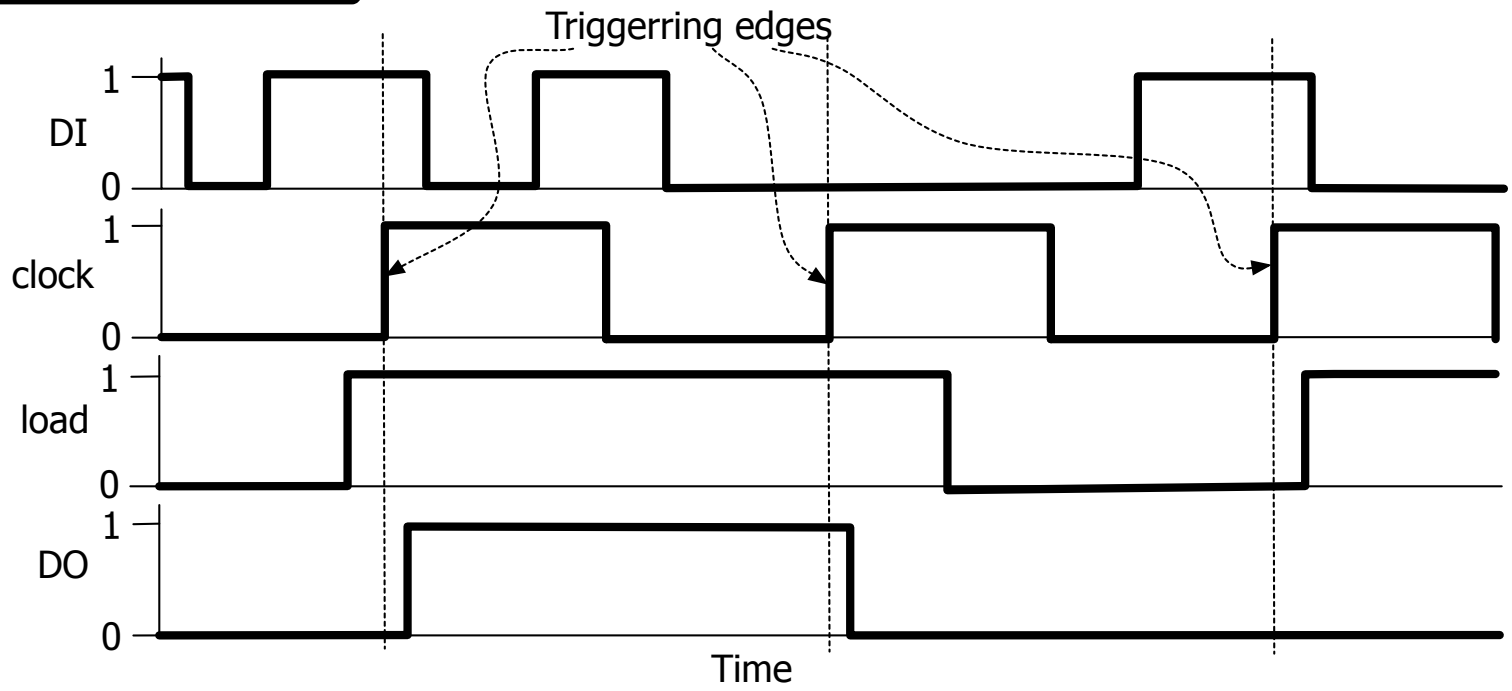


Registers

- A register is a storage device that can store binary information over time
  - It is a collection of one or more flip-flops



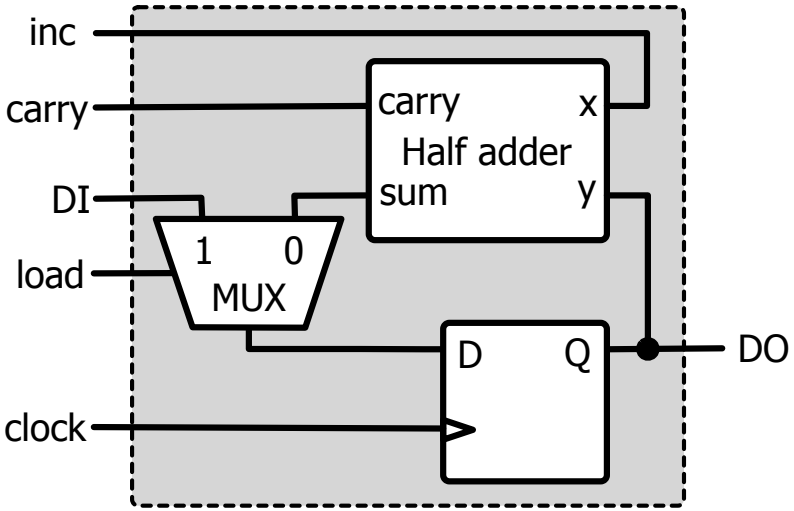


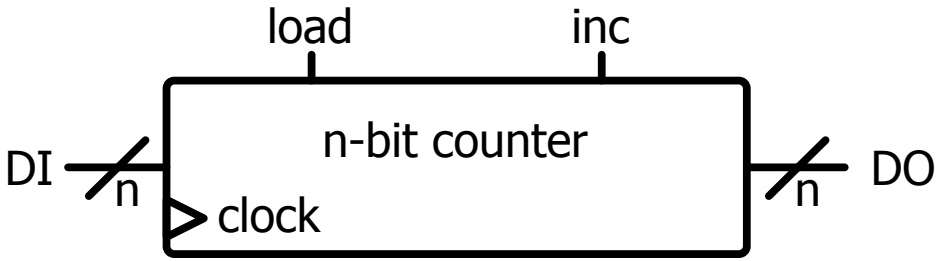


Binary Counters

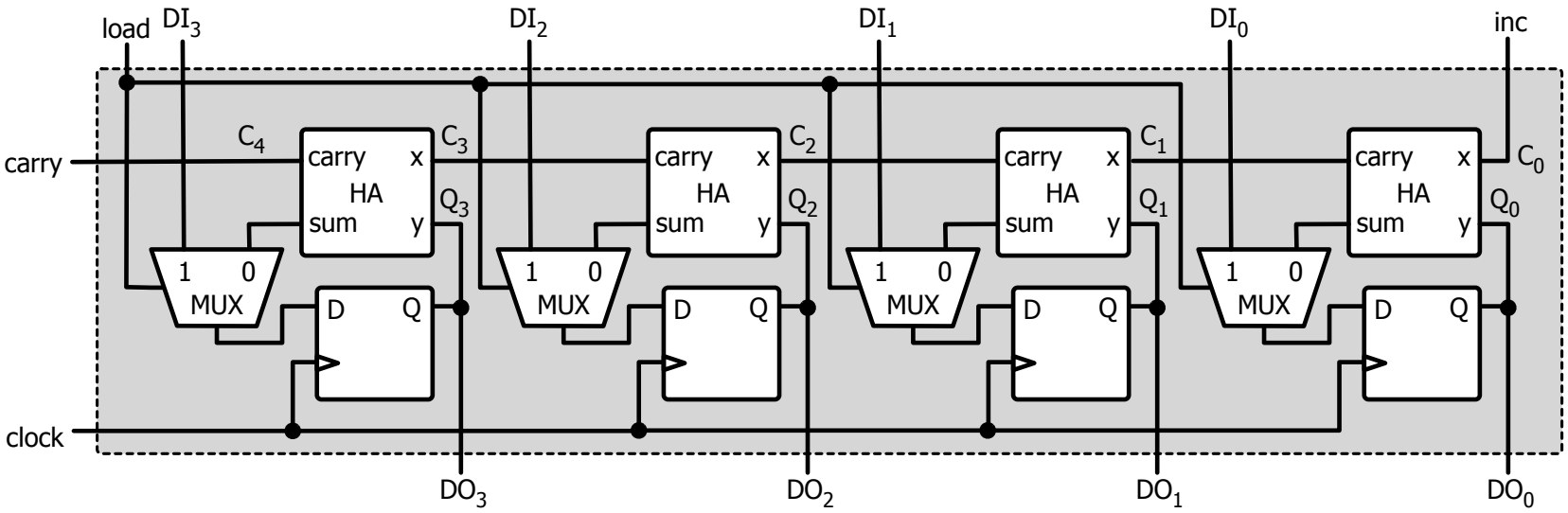
- An n-bit counter is an n-bit register that goes through a predetermined sequence of states upon the application of the clock signal
- A counter that follows the binary number sequence is called a binary counter

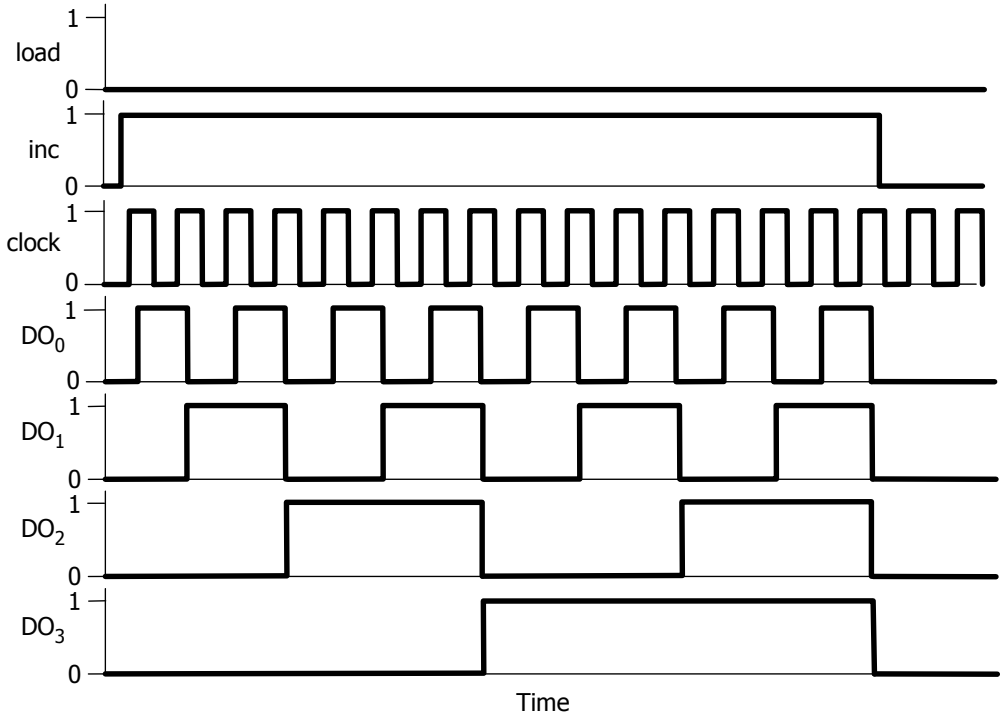
Binary Counters (contd.)





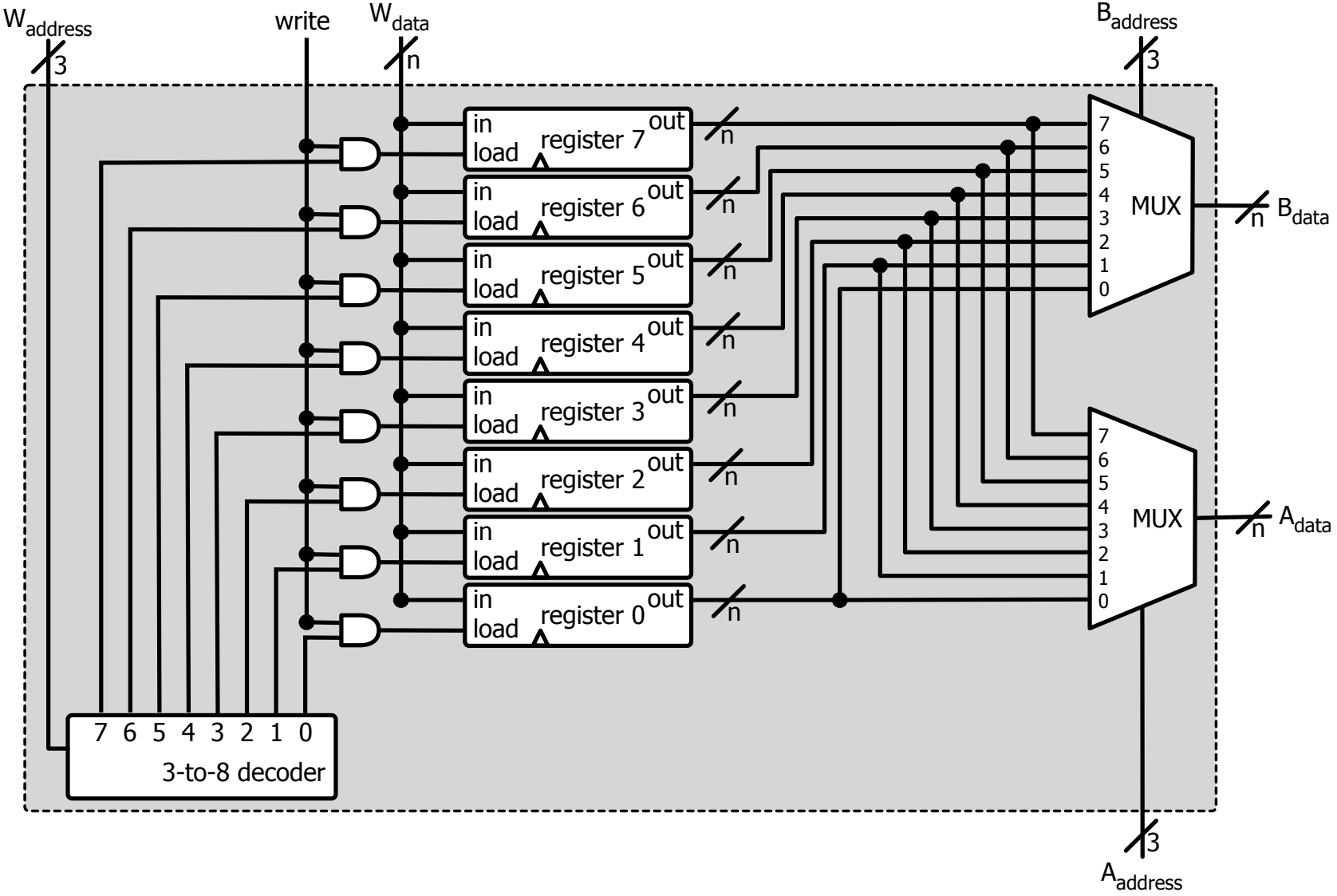
Binary Counters (contd.)





Register Files

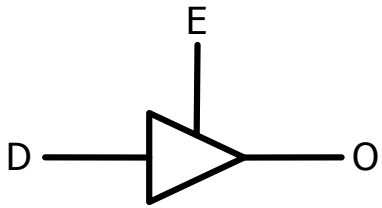
- A register file is an array of registers in a CPU

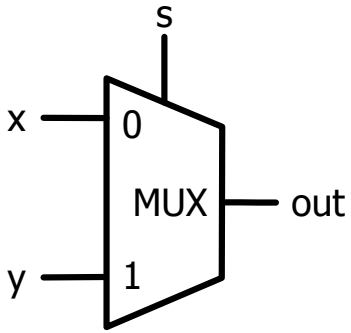


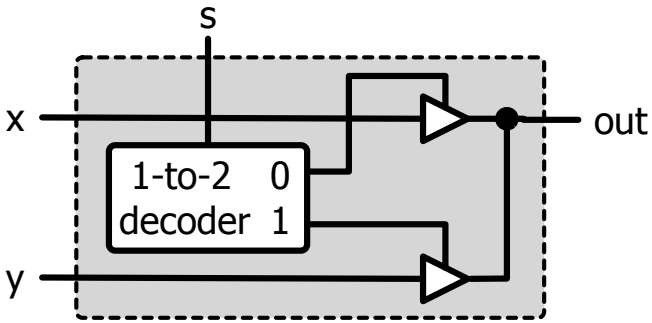
Tristate Buffers

- Also known as tristate drivers
- A third state, called a high-impedance state and denoted as Hi – Z, in addition to 0 and 1

E	D	O
0	X	Hi-Z
1	0	0
1	1	0



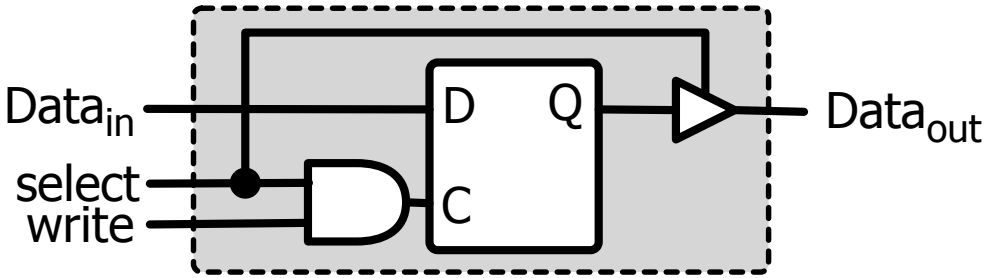


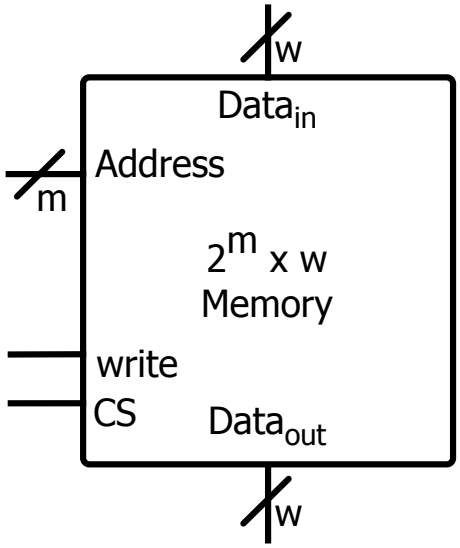


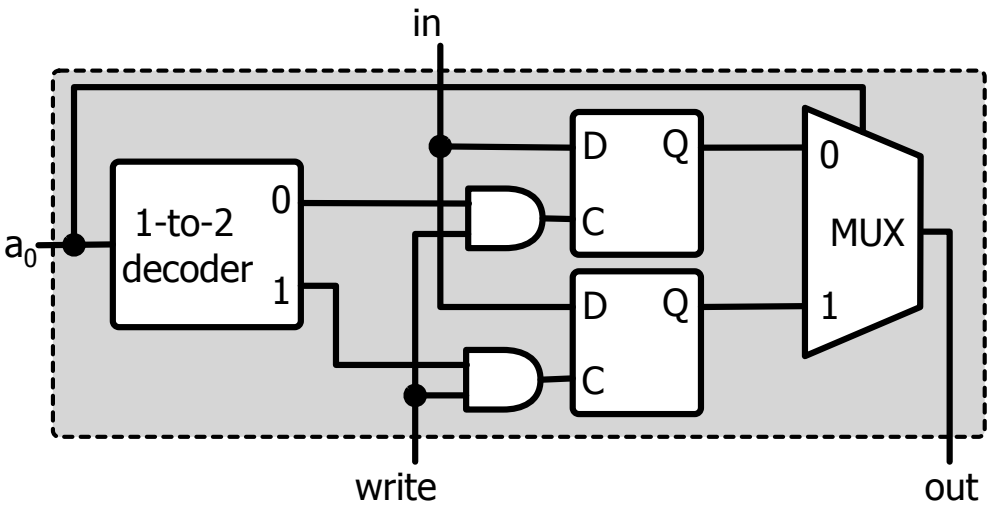
RAM

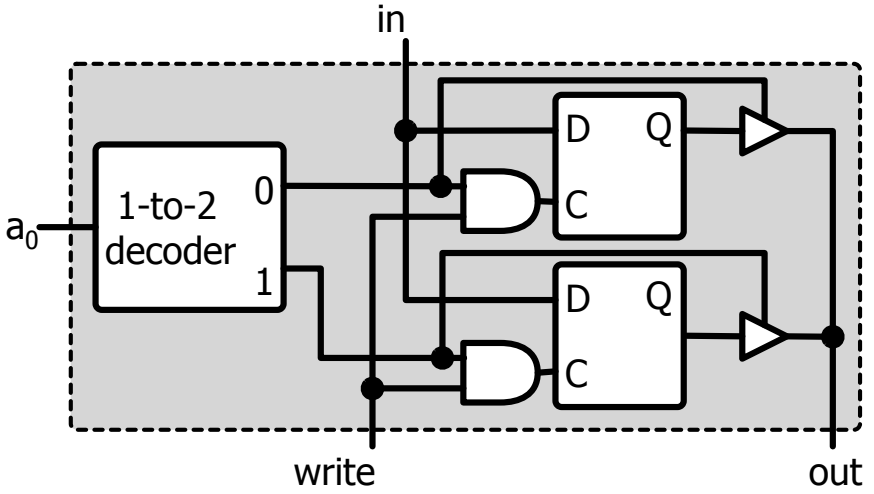
- Random access memory
- A word is a unit of information stored to and read from memory
- Able to access randomly chosen words regardless of the order in which they are accessed
- Thought as an array of 2^m w- bit registers + some access circuits to transfer information from/into it
  - Each word has a unique address

Memory Cell

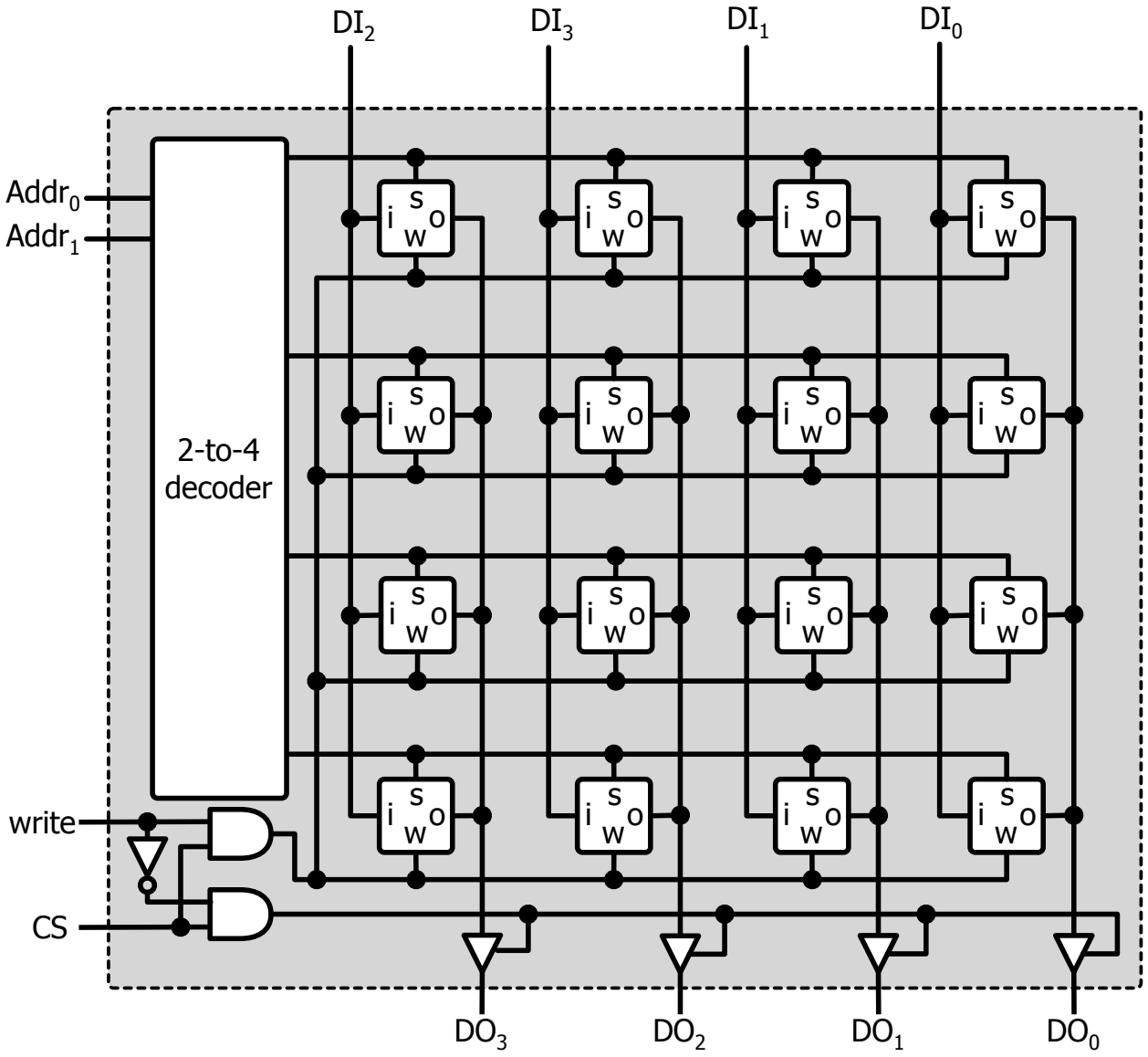

Data$_{in}$
select
write
D
Q
C
Data$_{out}$


w
Data$_{in}$
Address
m
2^m x w
Memory
write
CS
Data$_{out}$
w

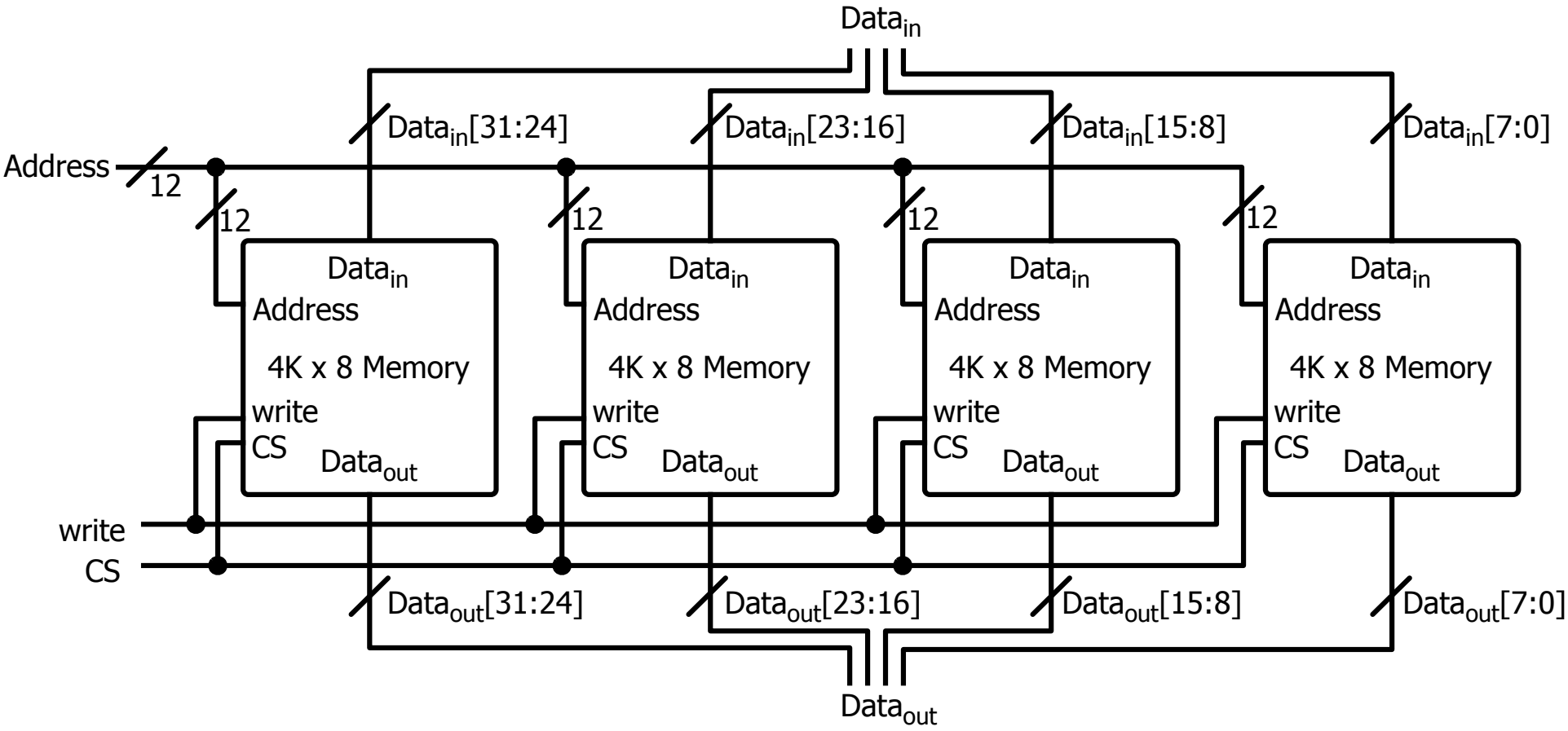

in
a_0
1-to-2
decoder
0
1
D
Q
C
D
Q
C
0
MUX
1
write
out


in
a_0
1-to-2
decoder
0
1
D
Q
C
D
Q
C
write
out

4 × 4 RAM


DI2
DI3
DI1
DI0
Addr0
Addr1
2-to-4
decoder
write
CS
DO3
DO2
DO1
DO0

Building a RAM with Bigger Words



Building a RAM with More Words