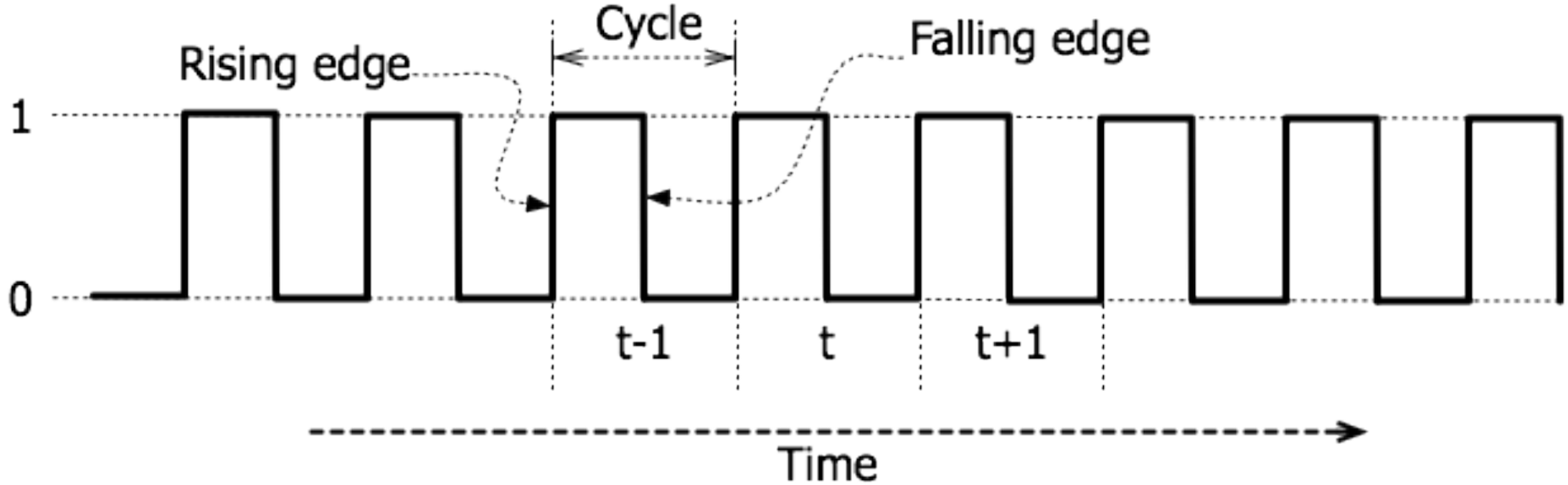
Logic Circuits II

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



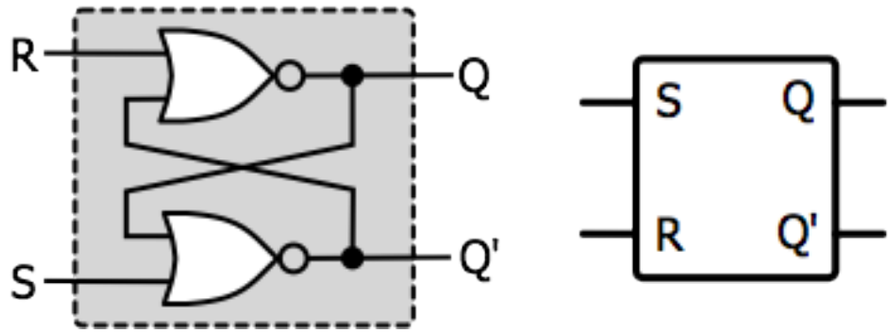
Gate Delay

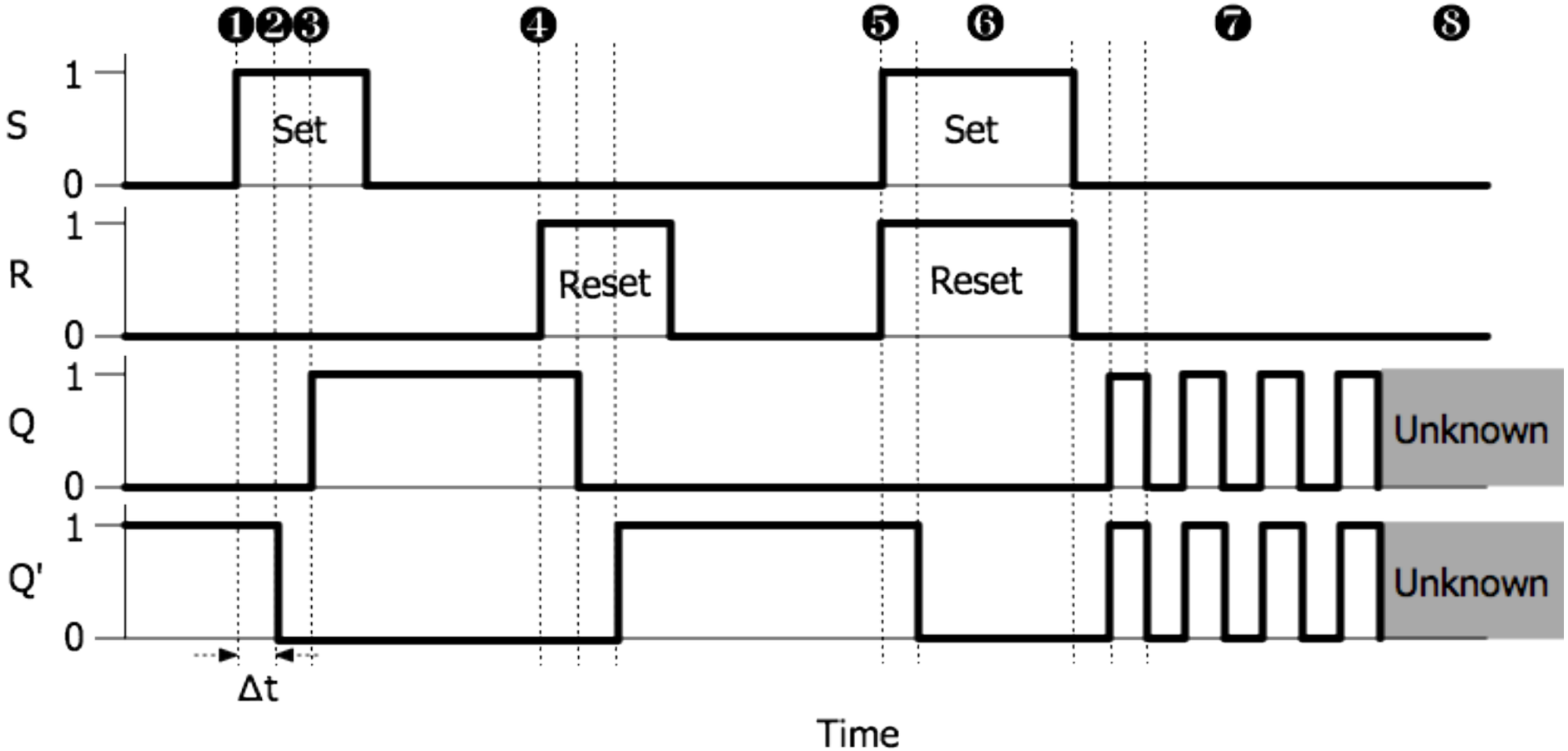
- Also known as propagation delay
- The time delay between the changes when an input change causes an output change

The SR Latch

S	R	Q
0	0	Q_{prev} (no change)
0	1	0
1	0	1
1	1	Undefined

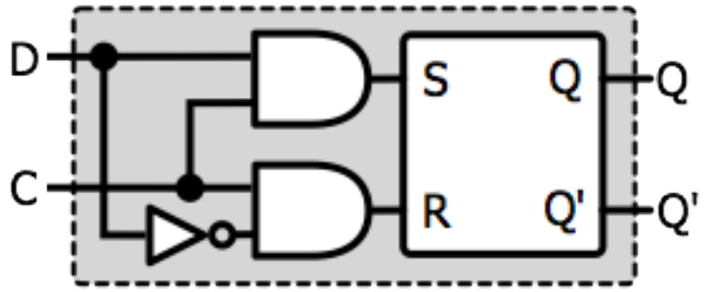
$$Q = S \vee (R' \wedge Q_{prev})$$

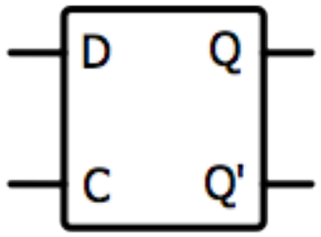


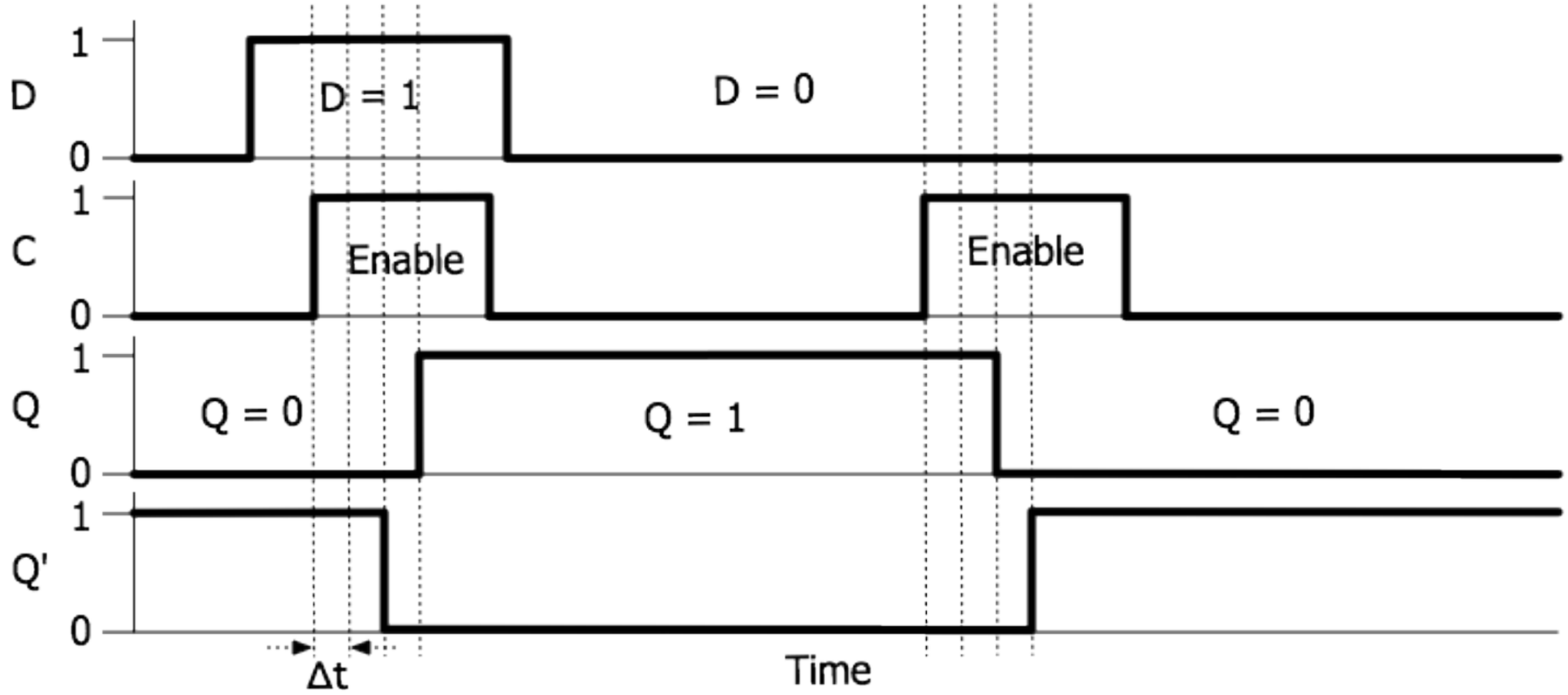


The D Latch

C	D	Q
0	X	Q_{prev} (no change)
1	0	0
1	1	1



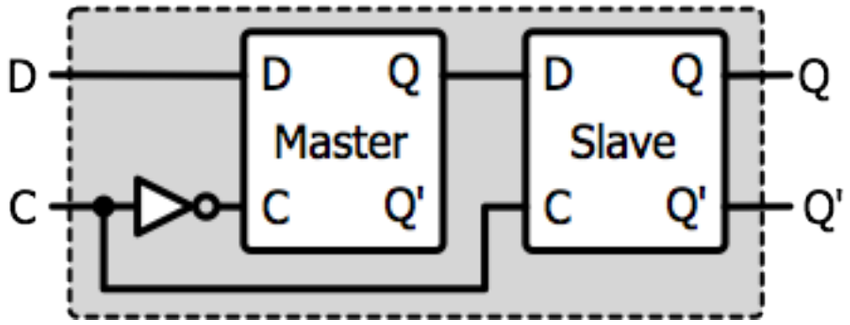


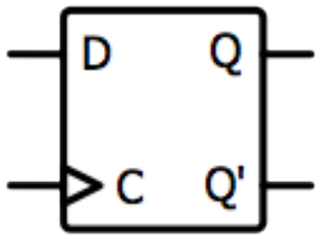


Latches vs. Flip-flops

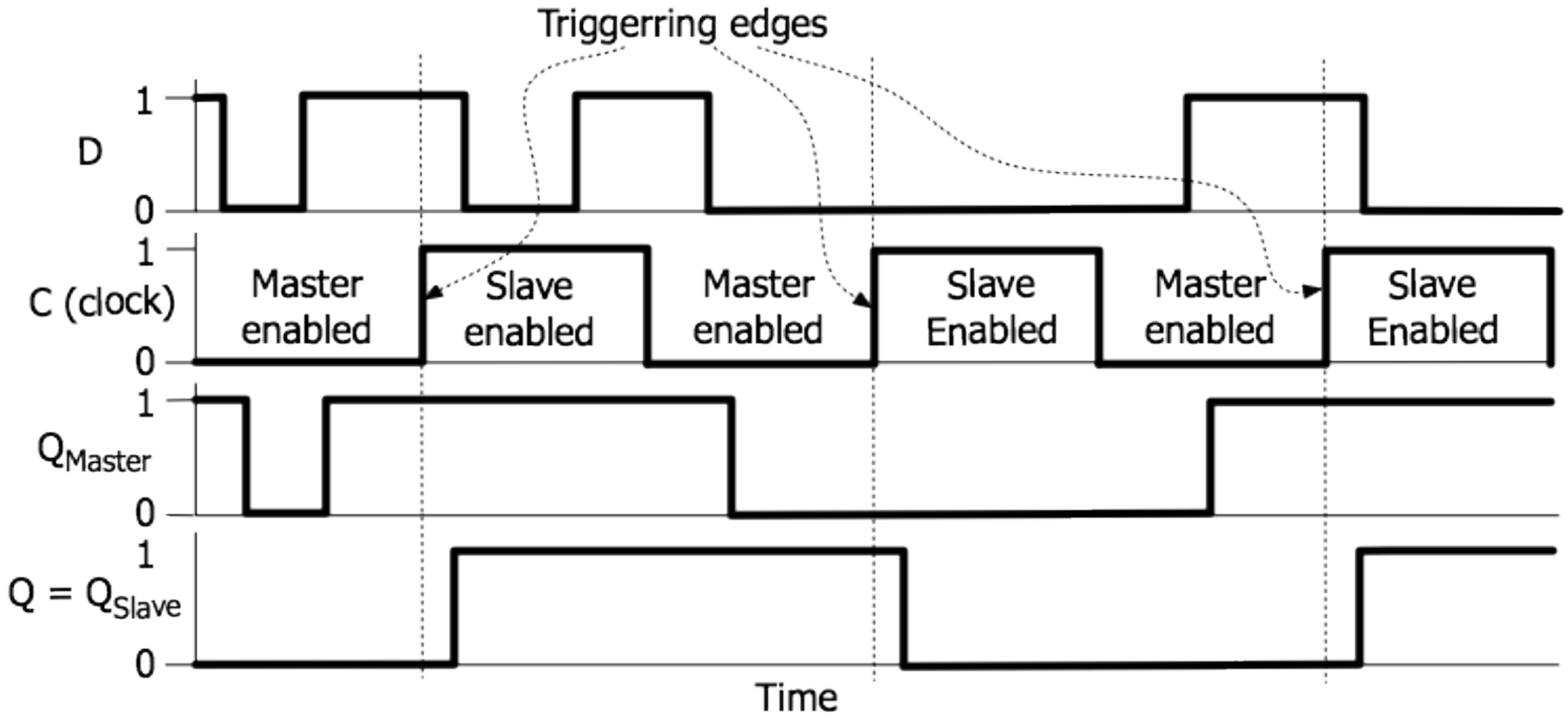
- Latches are transparent
  - As long as the control input C remains 1, the output of the D latch will momentarily change each time its input changes
- Flip-flops are not transparent
  - The key difference between latches and flip-flops

The D Flip-flop



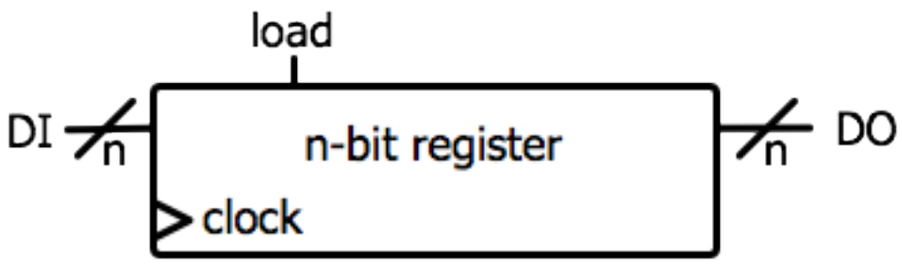


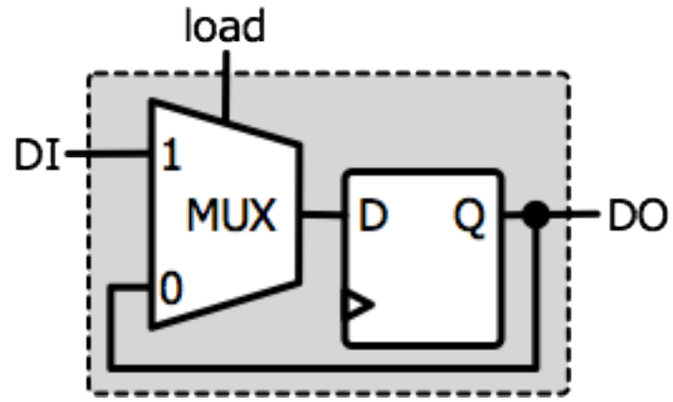
Asynchronous inputs:
preset and clear

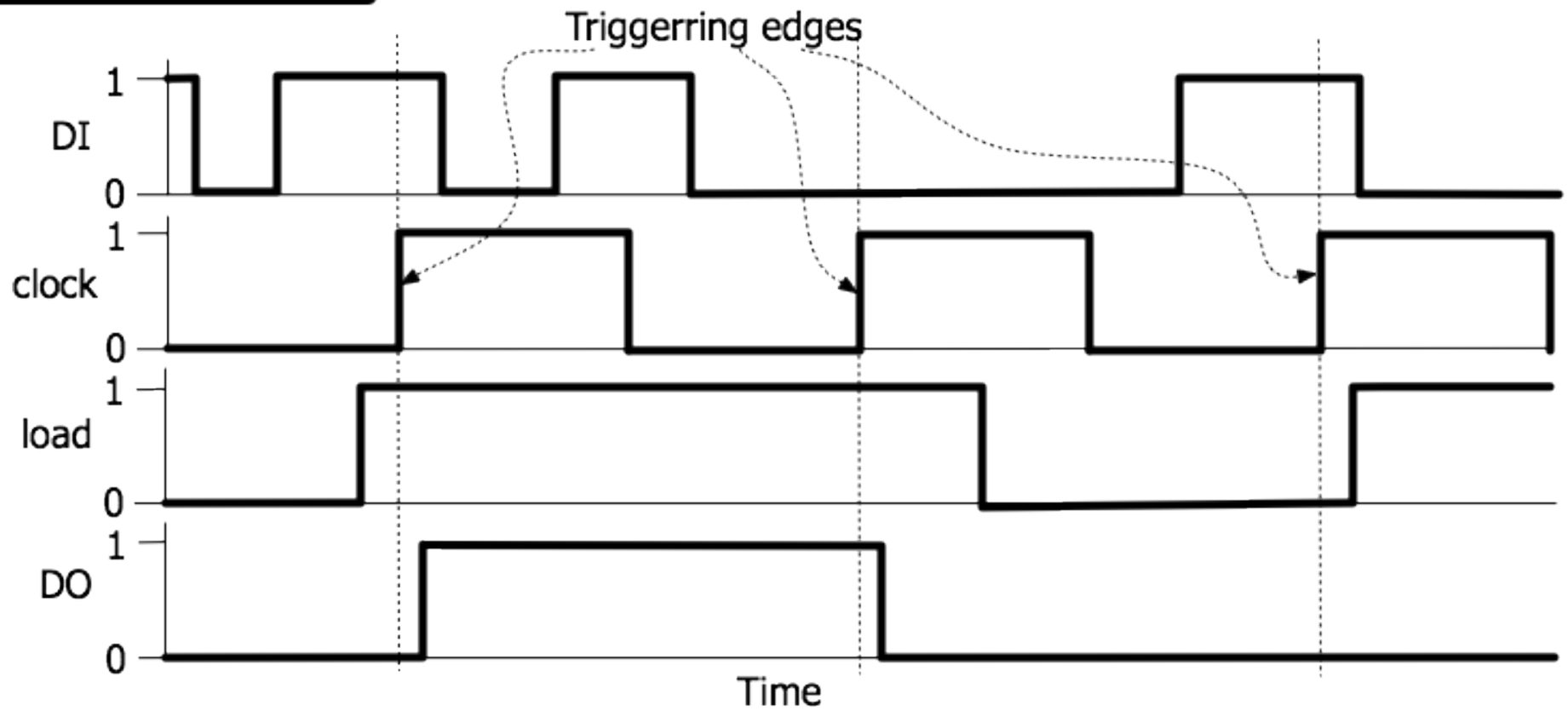


Registers

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



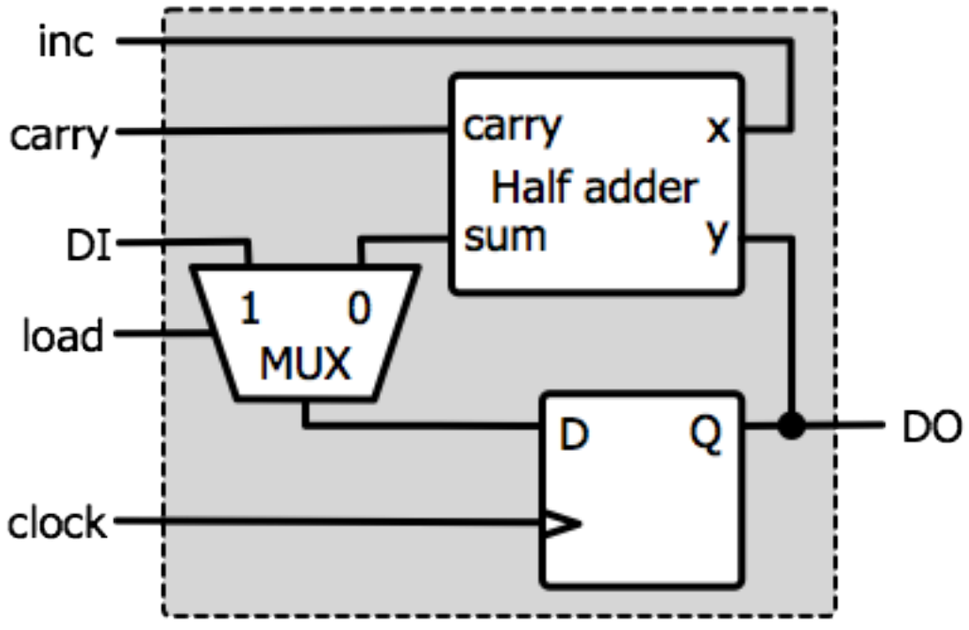


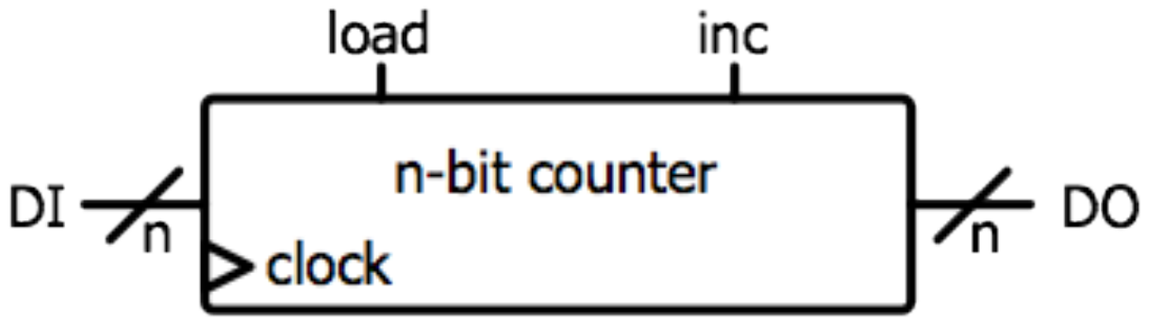


Binary Counters

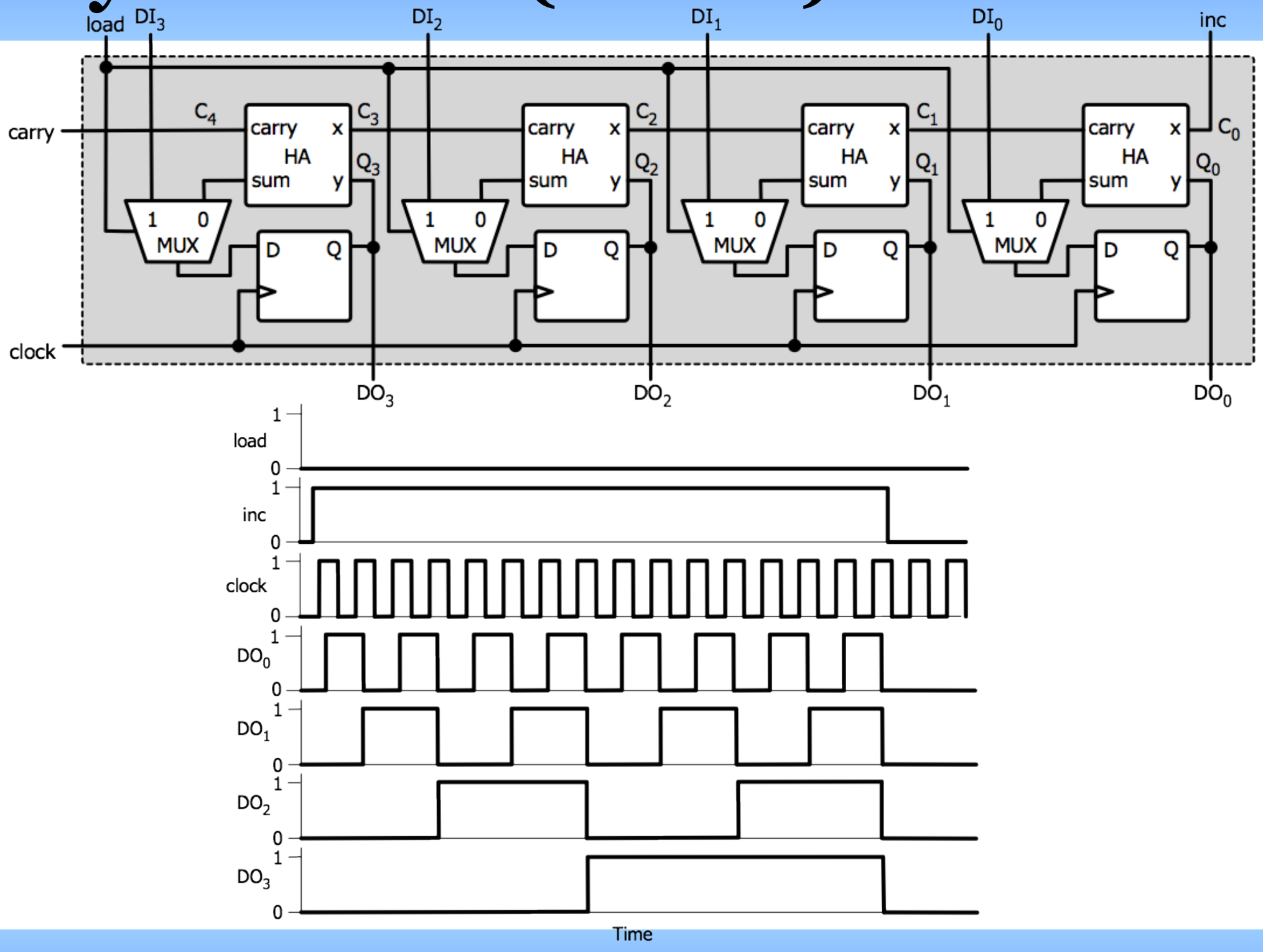
- An n-bit counter is an n-bit register that goes through a predetermined sequence of states upon the application of the clock signal
- A counter that follows the binary number sequence is called a binary counter

Binary Counters (contd.)



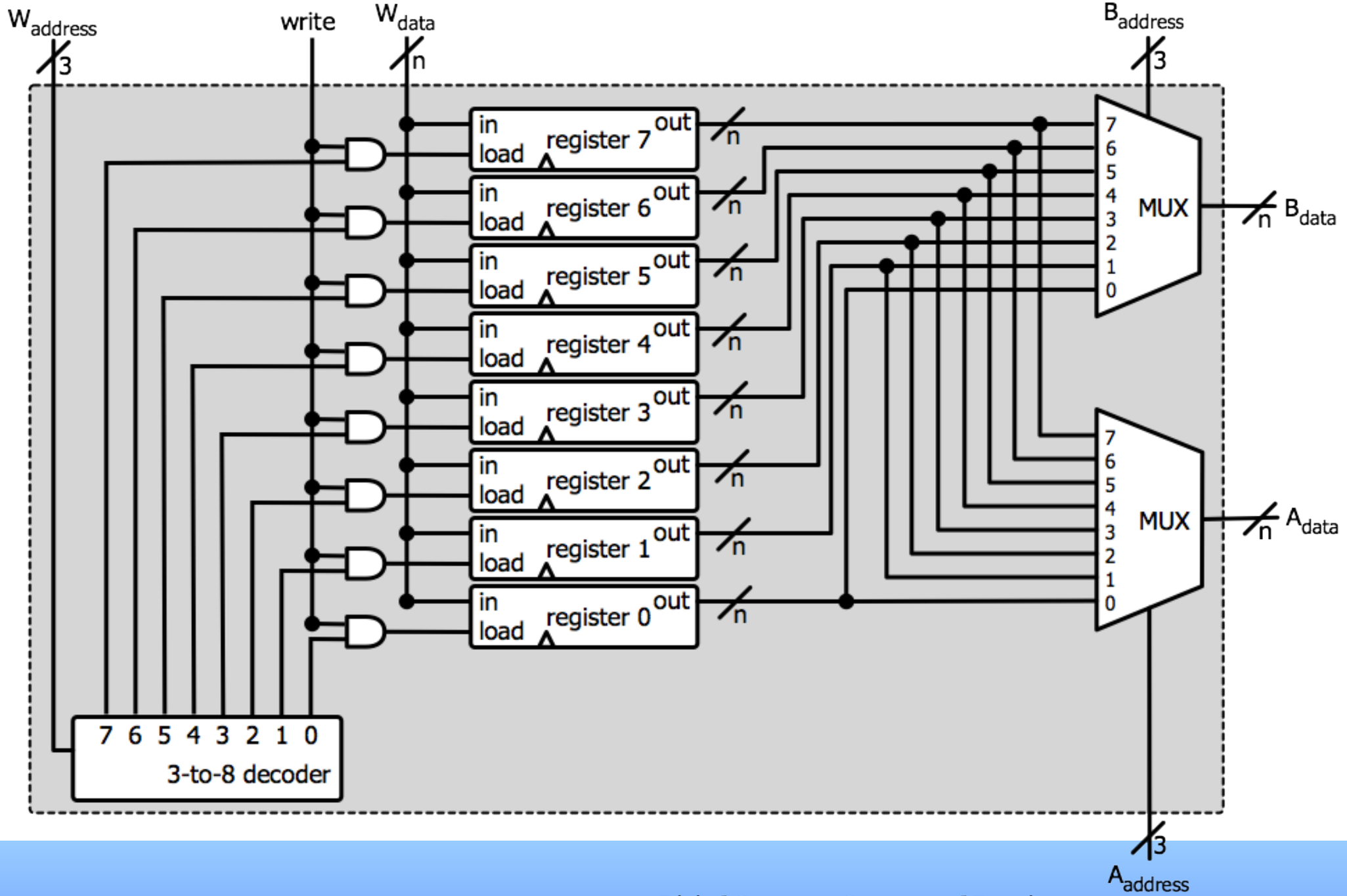


Binary Counters (contd.)



Register Files

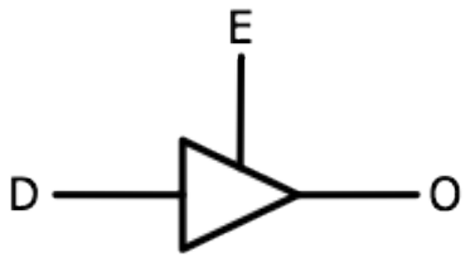
- A register file is an array of registers in a CPU

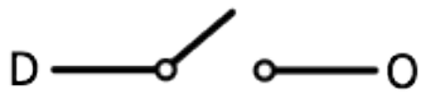


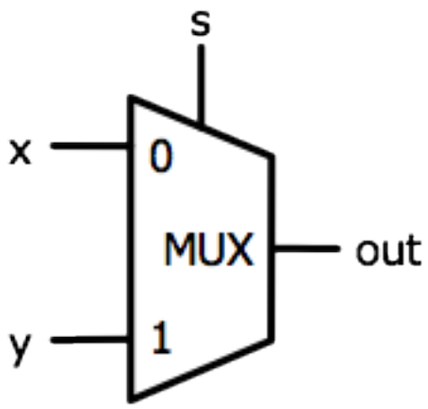
Tristate Buffers

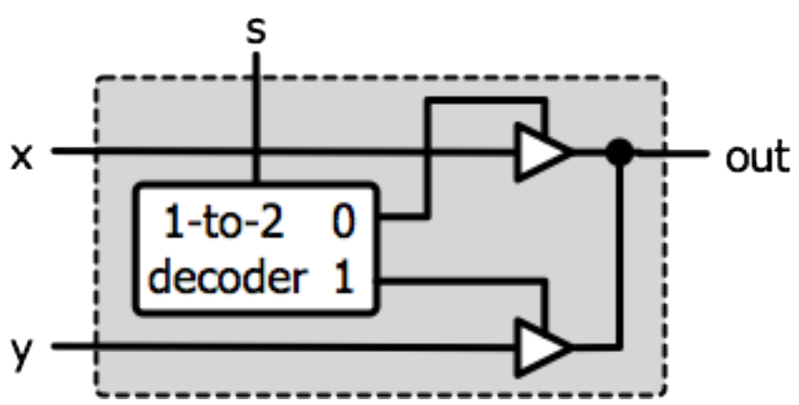
- Also known as tristate drivers
- A third state, called a high-impedance state and denoted as Hi – Z, in addition to 0 and 1

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





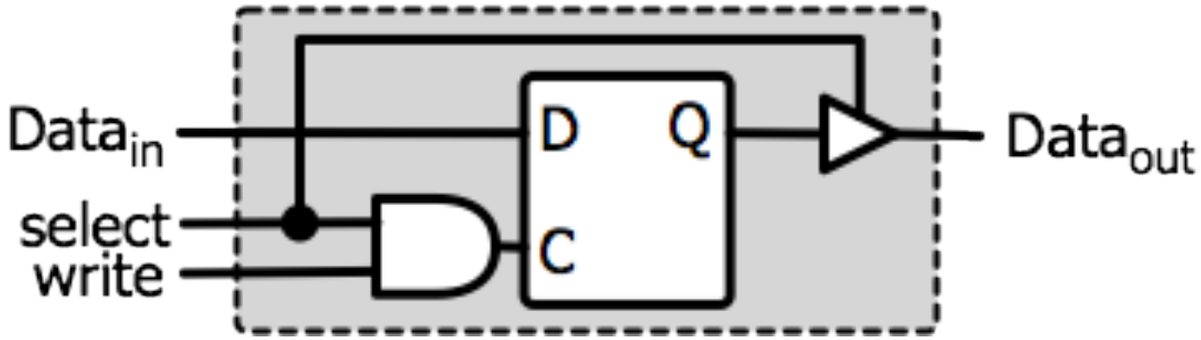


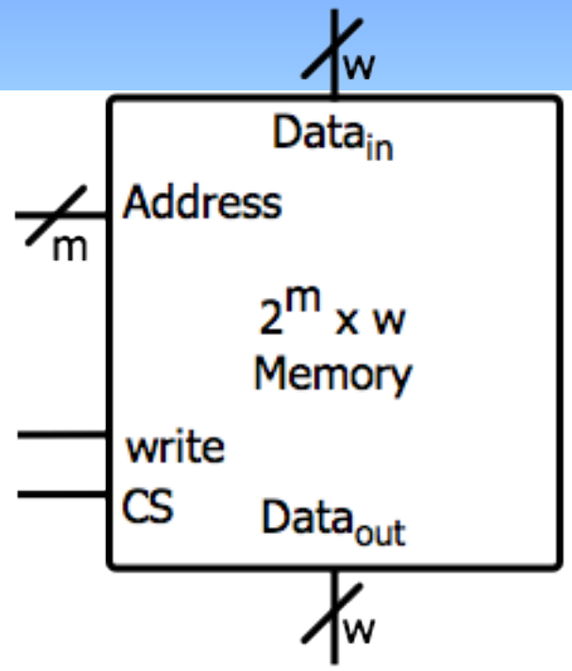


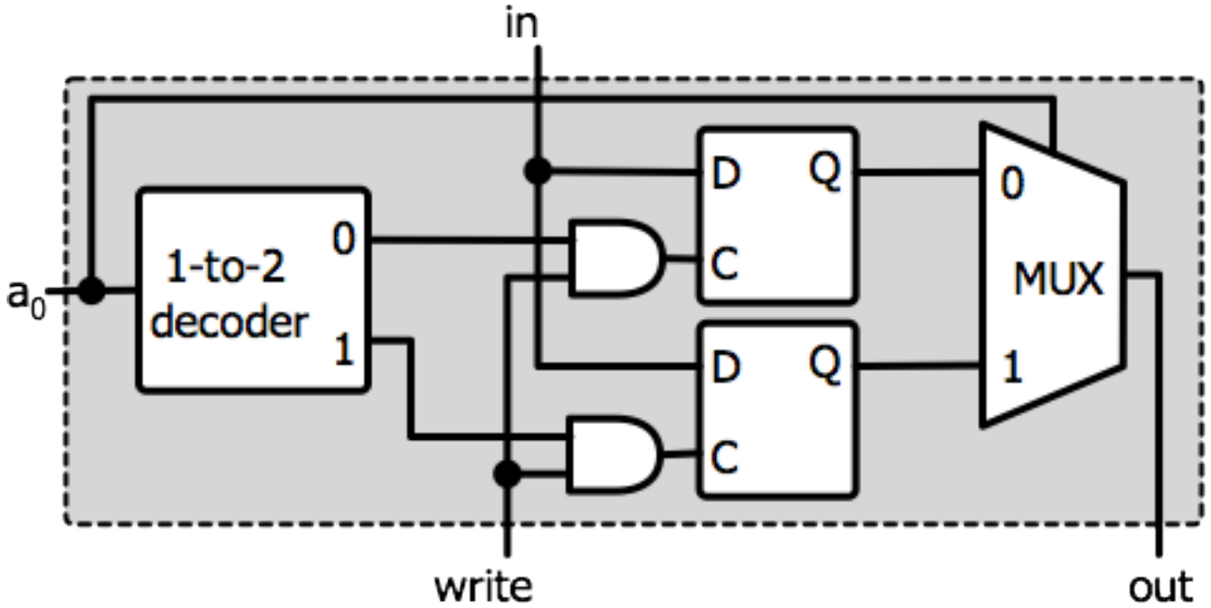
RAM

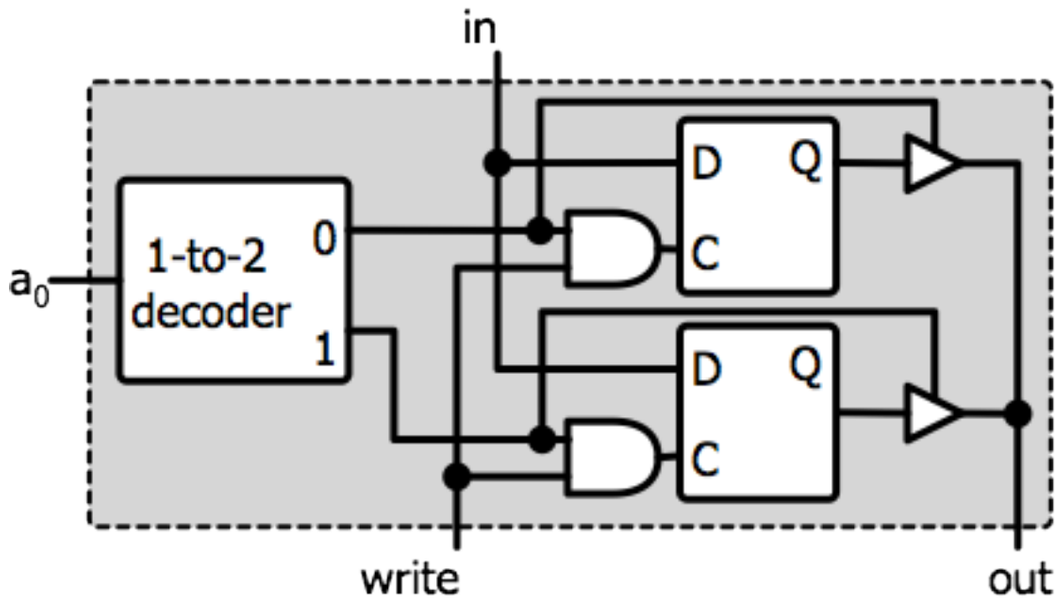
- Random access memory
- A word is a unit of information stored to and read from memory
- Able to access randomly chosen words regardless of the order in which they are accessed
- Thought as an array of 2^m w- bit registers + some access circuits to transfer information from/into it
  - Each word has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

Memory Cell

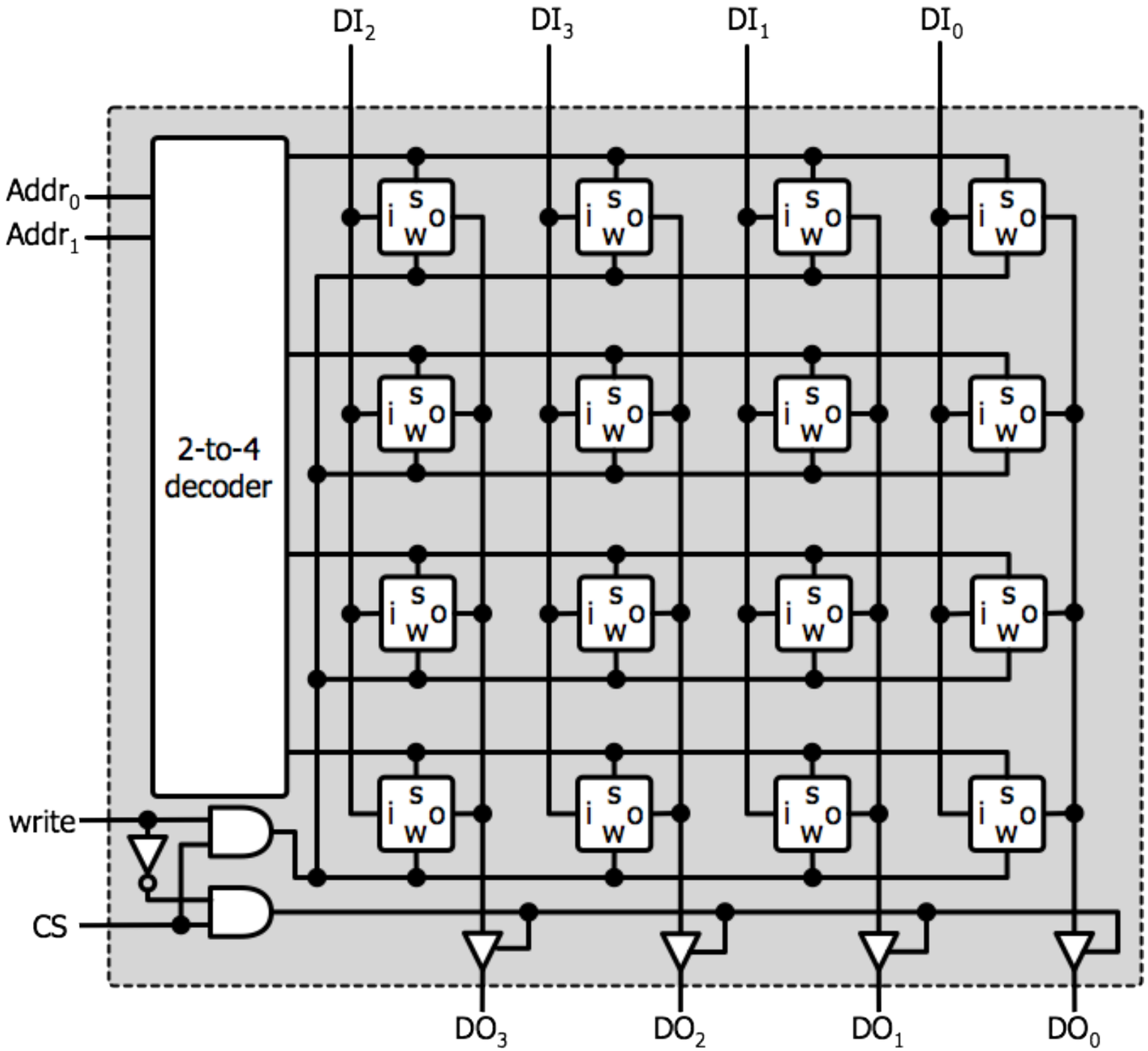




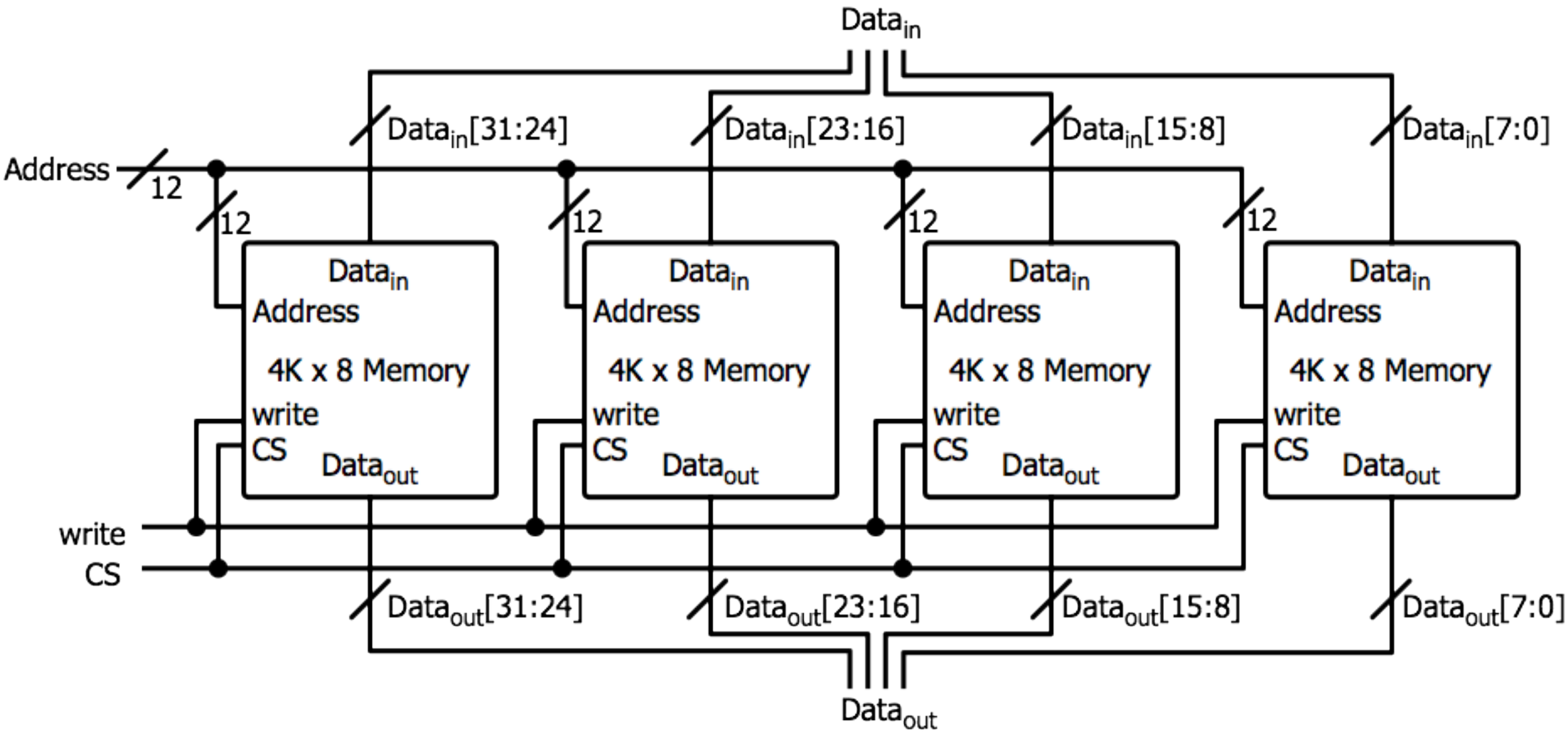




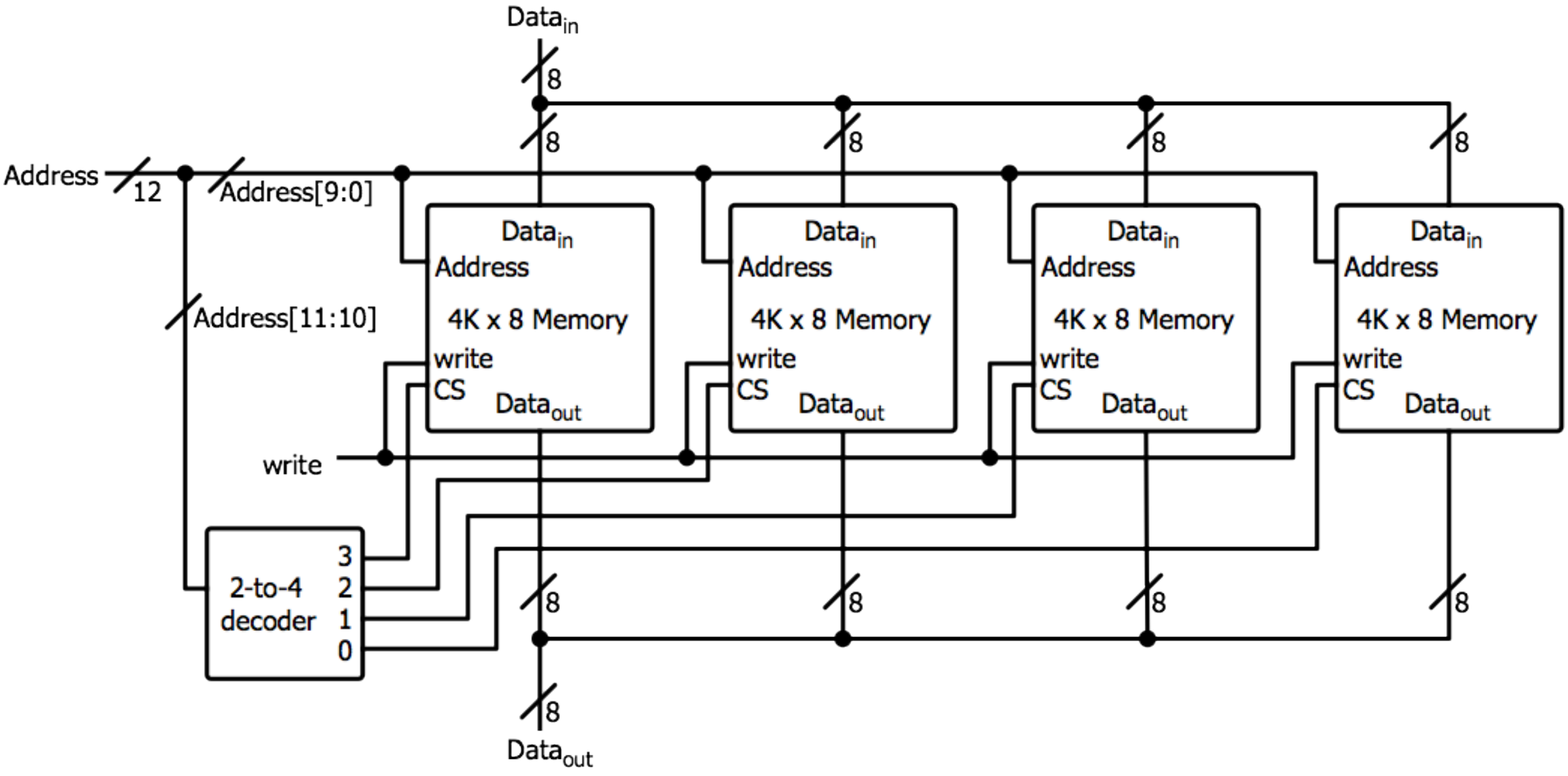
4 × 4 RAM



Building a RAM with Bigger Words

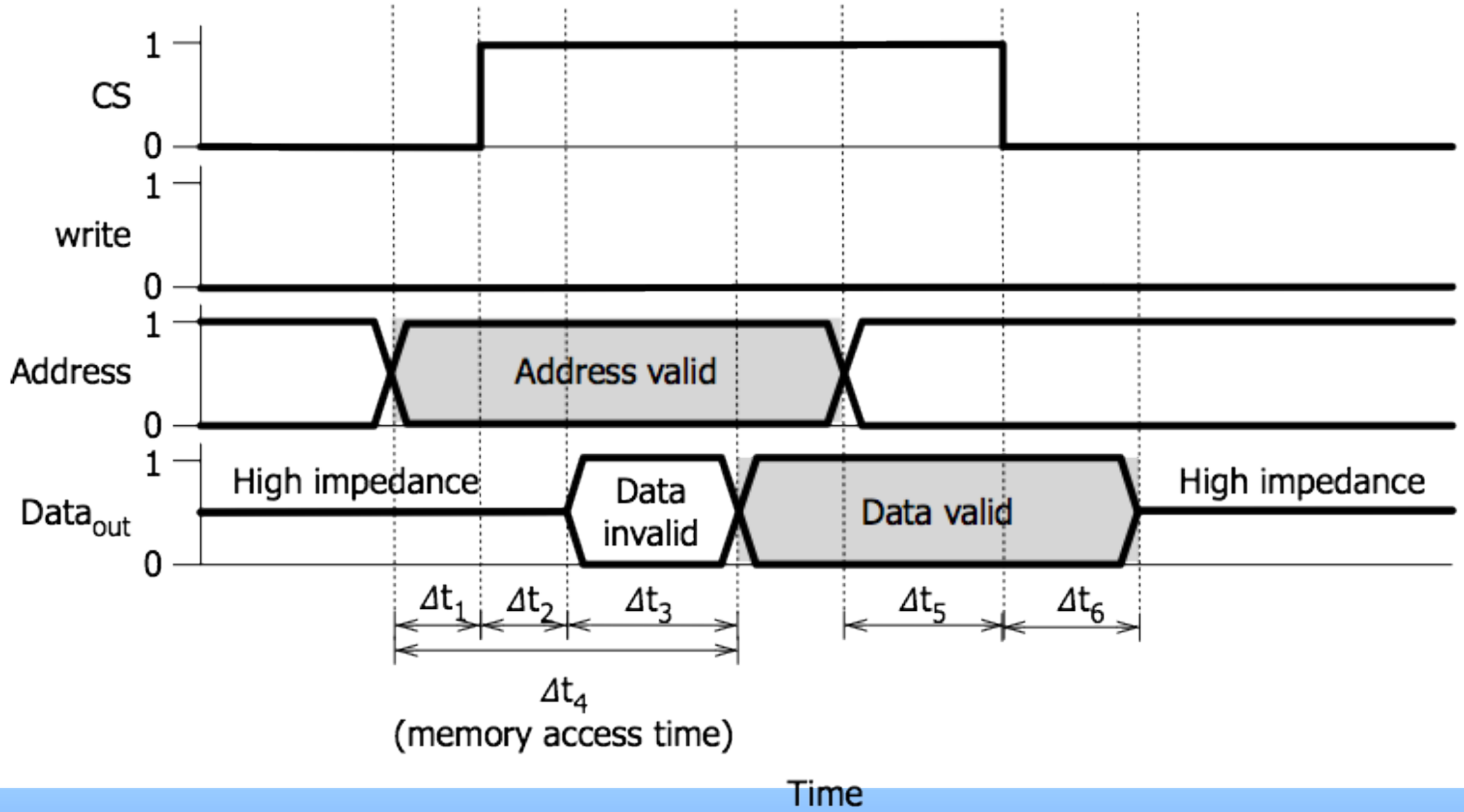


Building a RAM with More Words



RAM Read Cycle

- The maximum time (Δt1 + Δt2 + Δt3) taken between the application of the address to address lines and the appearance of the valid data on the data output lines is called memory access time



RAM Write Cycle