Lecture 24 – Memory architecture 1

Chapter 7

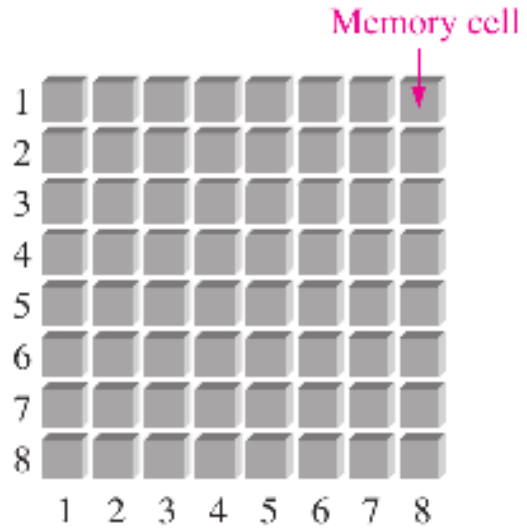
Memory

- Two major types of semiconductor memories are random-access memory (RAM)and read-only memory (ROM).
- RAM is a type of memory in which all contents are accessible in an equal amount of time and can be selected in any order for a read or write operation.
  - RAM has both read and write capability.
  - RAMs lose stored data when the power is turned off, they are *volatile memories*.

- ROM is a type of memory in which data are stored permanently or semi-permanently.
  - Data can be read from a ROM, but there is no write operation as in the RAM.
  - The ROM, like the RAM, is a random-access memory but the term RAM traditionally means a random-access read/write memory
  - Because ROMs retain stored data even if power is turned off, they are *nonvolatile* memories.

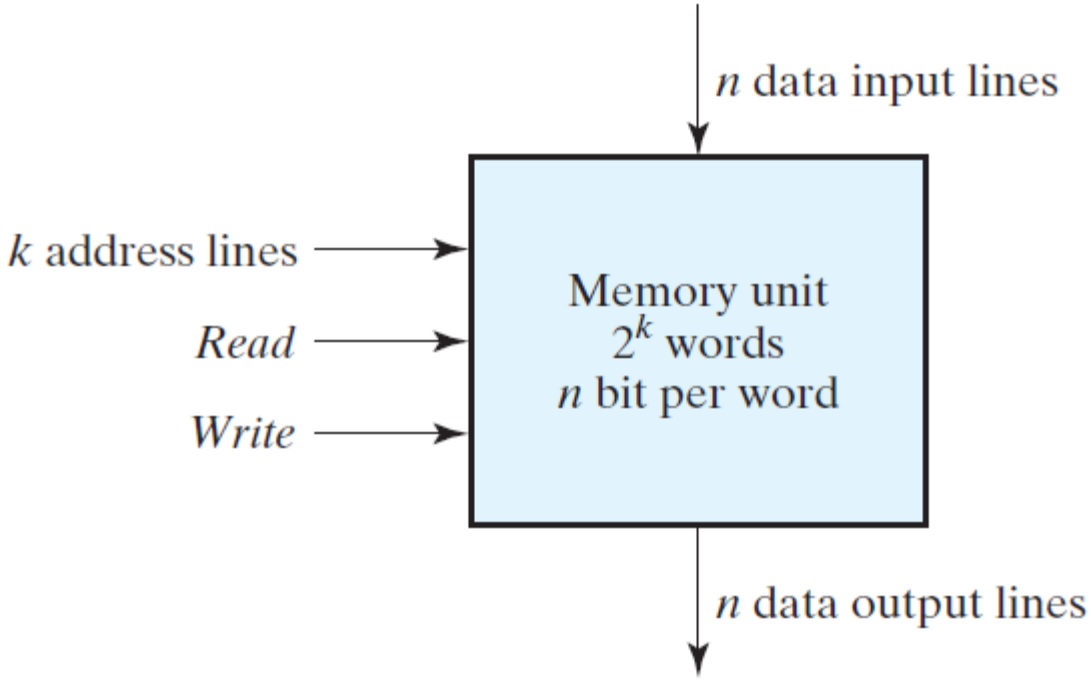
Random Access Memory (RAM)

- A memory unit is a collection of storage cells, together with associated circuits needed to transfer information into and out of a device
- The architecture of memory is such that information can be selectively retrieved from any of its internal locations
- The time it takes to transfer information to or from any desired random location is always the same—hence the name *random-access memory,* abbreviated RAM
- In contrast, the time required to retrieve information that is stored on magnetic tape, optical disks, etc, depends on the location of the data
- A memory unit stores binary information in groups of bits called *words*
- A word in memory is an entity of bits that move in and out of storage as a unit
- Most computer memories use words that are multiples of 8 bits in length
- The capacity of a memory unit is usually stated as the total number of bytes that the unit can store



Random Access Memory (RAM)

- Communication between memory and its environment is achieved through data input and output lines, address selection lines, and control lines that specify the direction of transfer
- The *n* data input lines provide the information to be stored in memory, and the *n* data output lines supply the information coming out of memory
- The *k* address lines specify the particular word chosen among the many available
- The two control inputs specify the direction of transfer desired: The *Write* input causes binary data to be transferred into the memory, and the *Read* input causes binary data to be transferred out of memory
- The address lines select one particular word

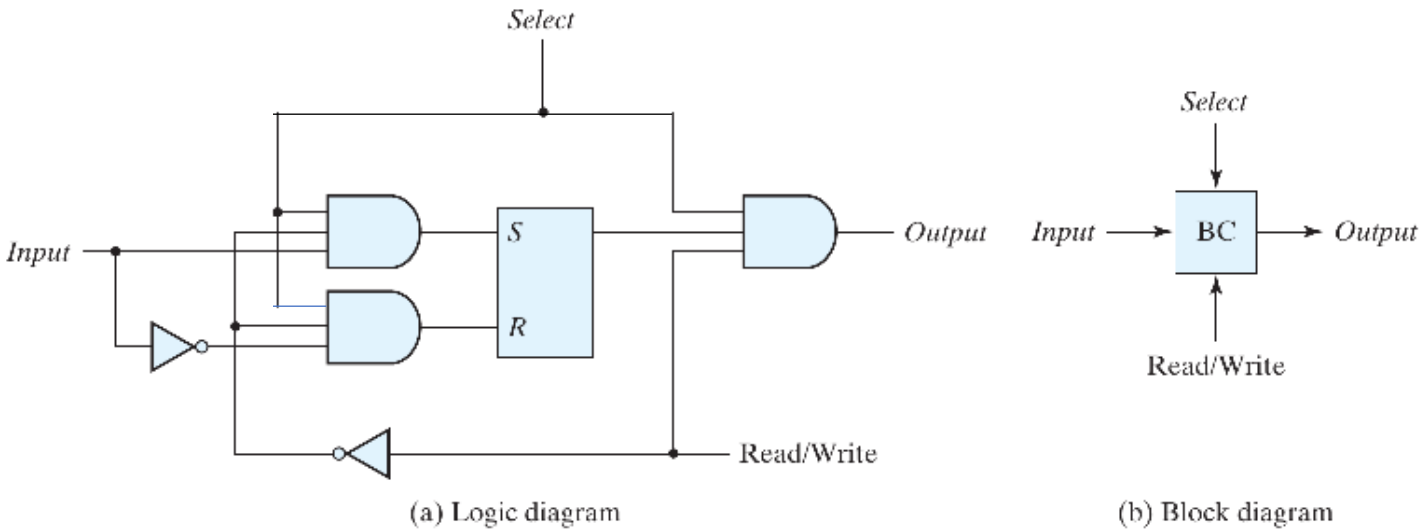


Random Access Memory (RAM)

- Consider, for example, a memory unit with a capacity of 1K words of 16 bits each
- Since 1K = 1,024 = 2^{10} and 16 bits constitute two bytes, we can say that the memory can accommodate 2,048 = 2Kb
- The words are recognized by their decimal address from 0 to 1,023
- The equivalent binary address consists of 10 bits
- A word in memory is selected by its binary address
- *When a word is read or written, the memory operates on all 16 bits as a single unit*

Memory address		Memory content
Binary	Decimal	
0000000000	0	1011010101011101
0000000001	1	1010101110001001
0000000010	2	0000110101000110
⋮	⋮	⋮
1111111101	1021	1001110100010100
1111111110	1022	0000110100011110
1111111111	1023	1011111000100101

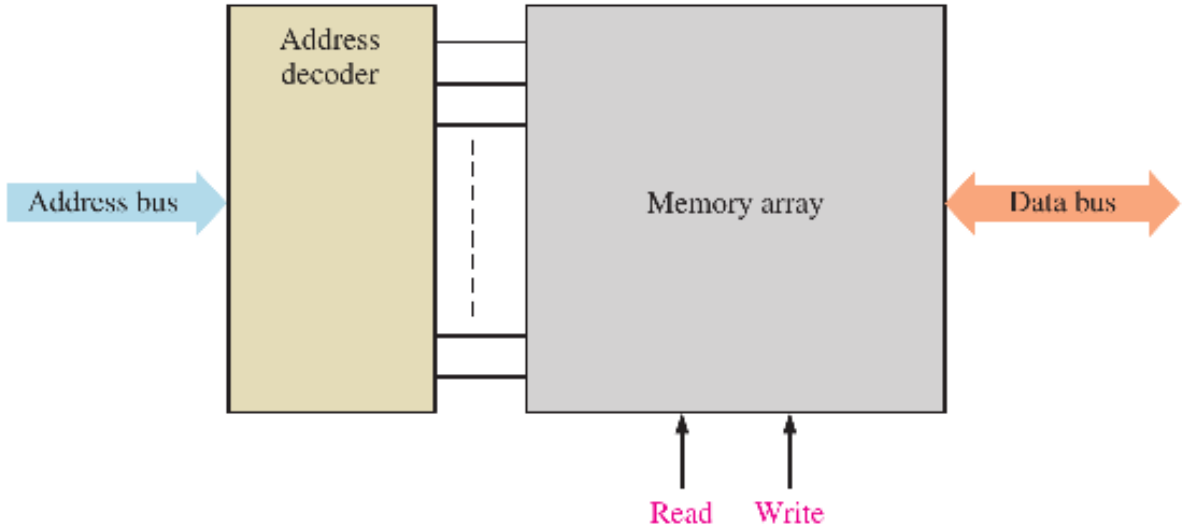
Random Access Memory (RAM) – internal structure



- The internal construction of a RAM of *m* words and *n* bits per word consists of *m* * *n* binary storage cells and associated decoding circuits for selecting individual words
- The binary storage cell (SR latch) is the basic building block of a memory unit
- The storage part of the cell is modeled by an *SR* latch with associated gates to form a *D* latch
- *Note that this is not a D flip-flop*

Write and Read operations

- The two operations that RAM can perform are the write and read operations
- The write signal specifies a transfer-in operation and the read signal specifies a transfer-out operation
- On accepting one of these control signals, the internal circuits inside the memory provide the desired operation

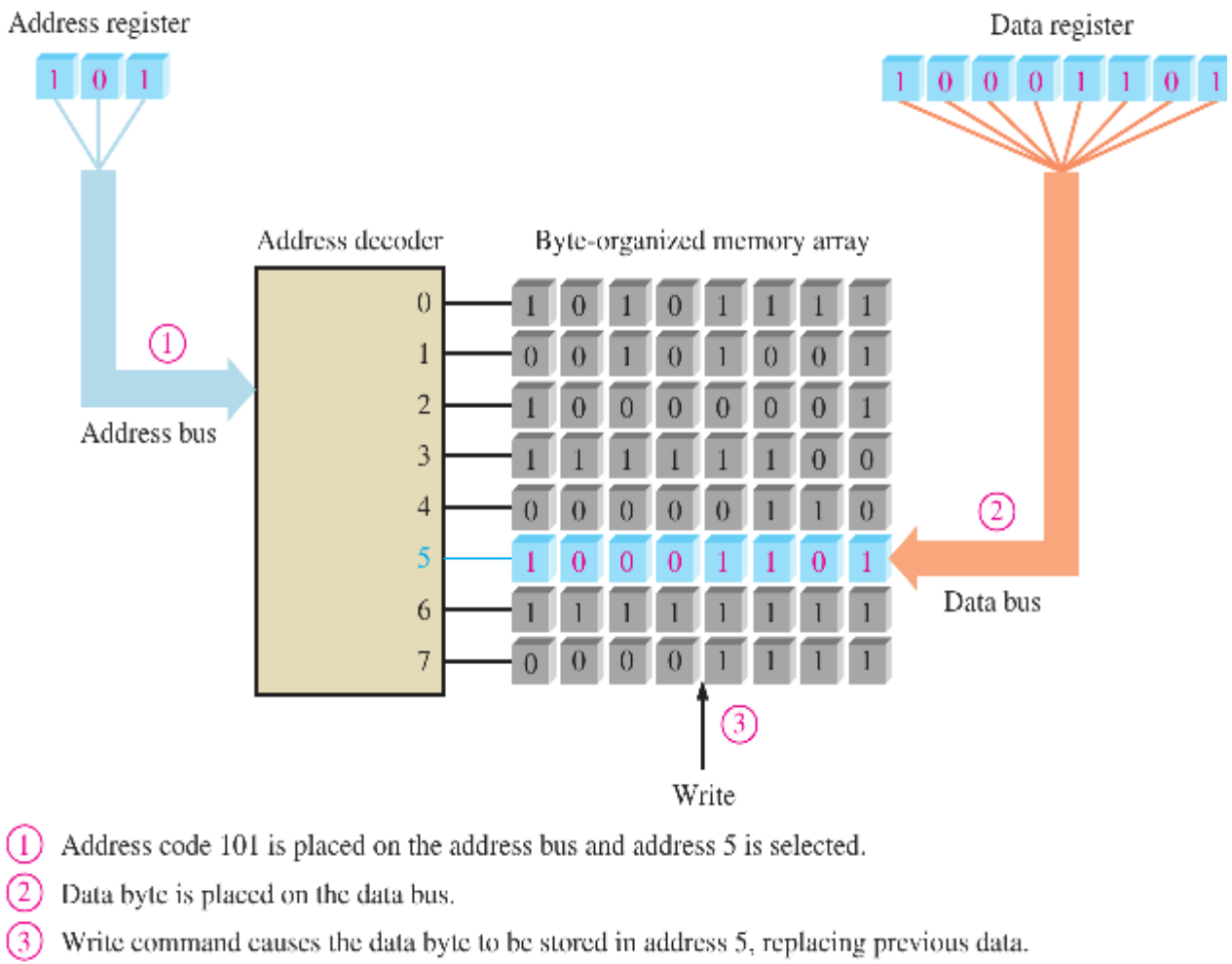


Write operation

- The steps that must be taken for the purpose of transferring a new word to be stored into memory are as follows:

1. Apply the binary address of the desired word to the address lines.
2. Activate the *write* input.
3. Apply the data bits that must be stored in memory to the data input lines.

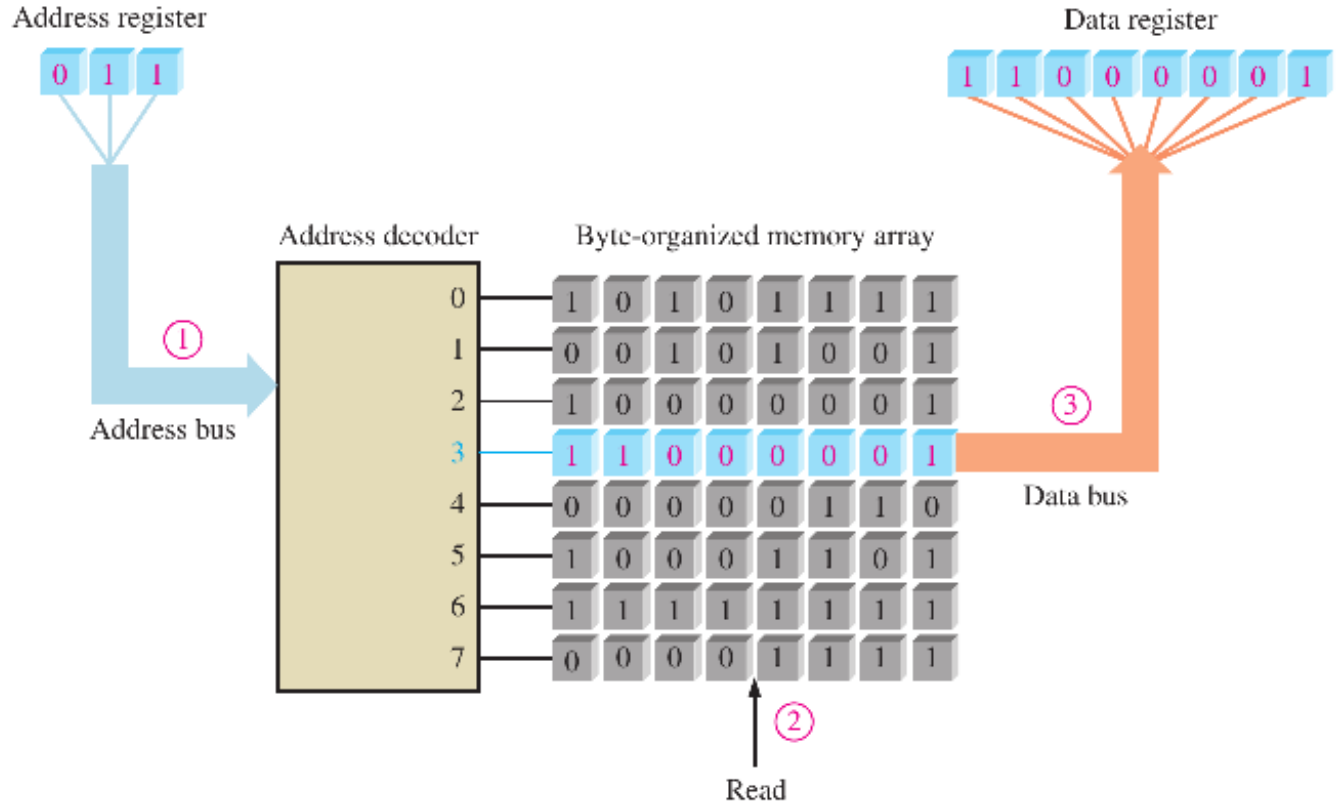
- The memory unit will then take the bits from the input data lines and store them in the word specified by the address lines



Read operation

- The steps that must be taken for the purpose of transferring a stored word out of memory are as follows:

1. Apply the binary address of the desired word to the address lines
2. The data shows up on the output lines after a certain delay from the application of the stable address (selecting the word)

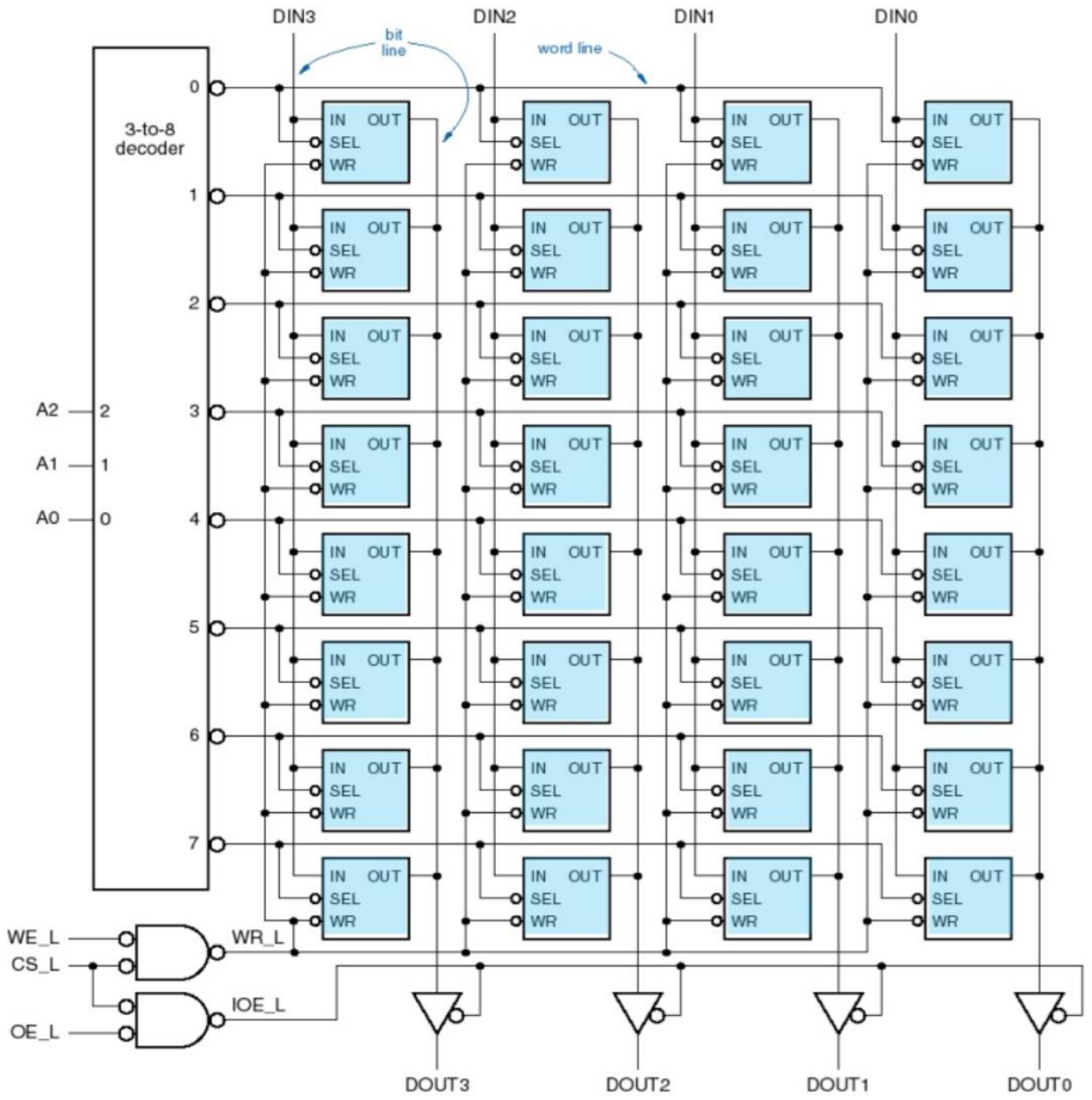


① Address code 011 is placed on the address bus and address 3 is selected.
② Read command is applied.
③ The contents of address 3 is placed on the data bus and shifted into data register. The contents of address 3 is not erased by the read operation.

Memory design

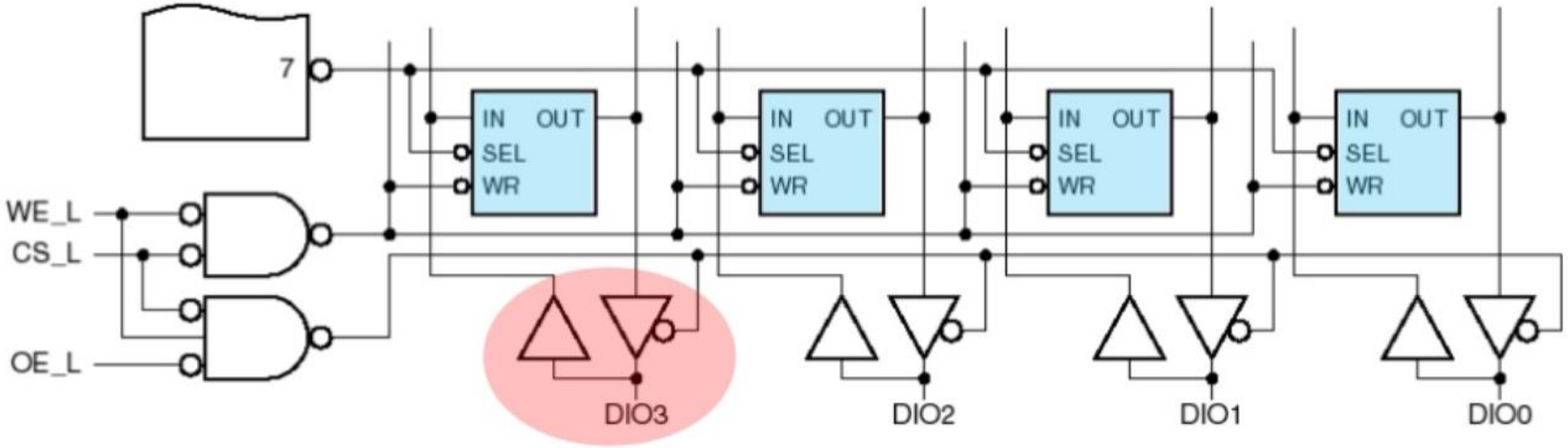
- The design of a memory will consist of a decoder circuit to select a particular "word line" based on the address
- The write enable, chip select and other inputs are common to all the latches
- The "bit line" determines what the bit at a particular position in the word will be

WE – write enable
CS – chip select
OE – output enable



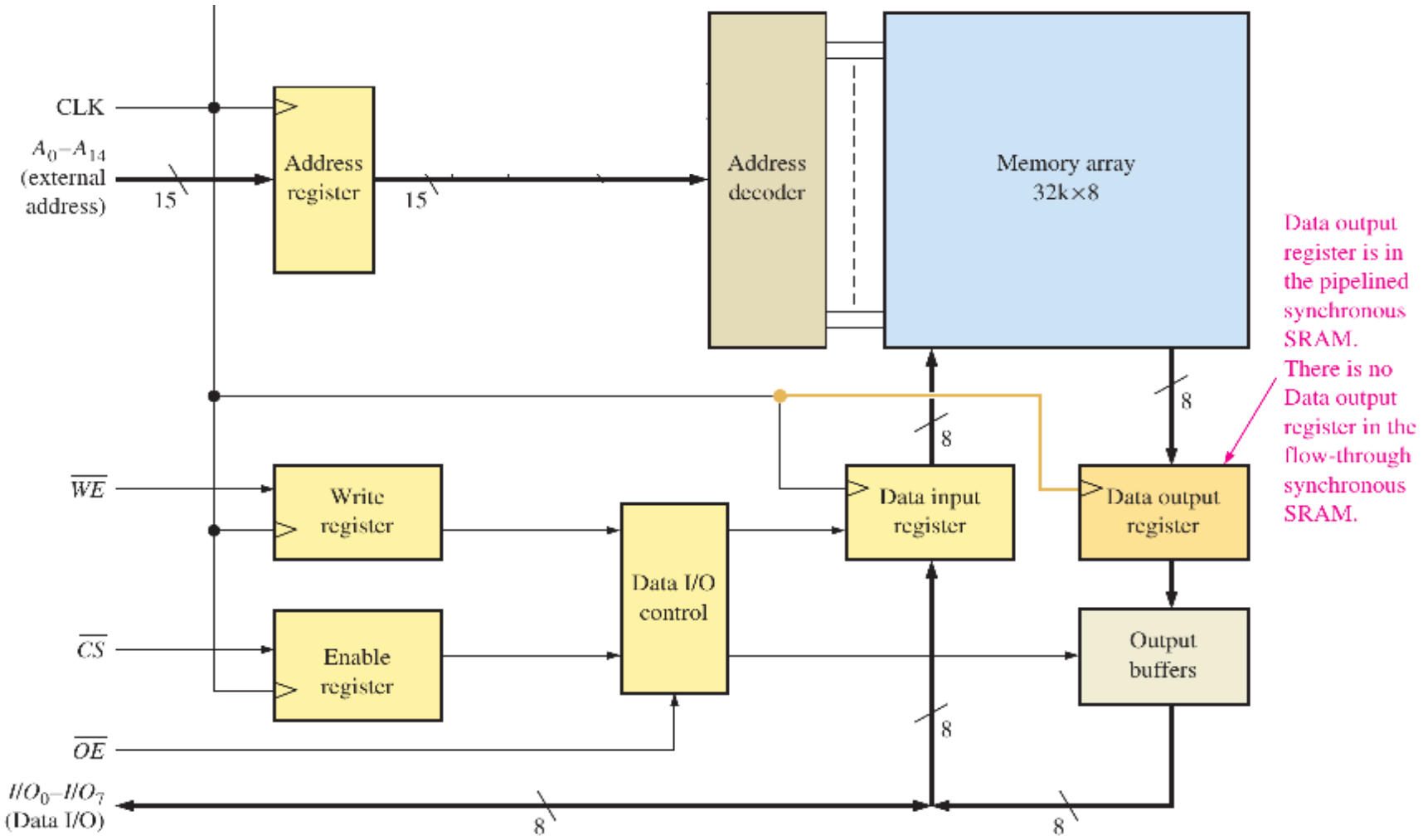
Memory design

- We can modify the output such that we have the same lines for both input and output case
- This is very common both inside the processor (internal buses) and outside the processor (such as digital IO or GPIO)

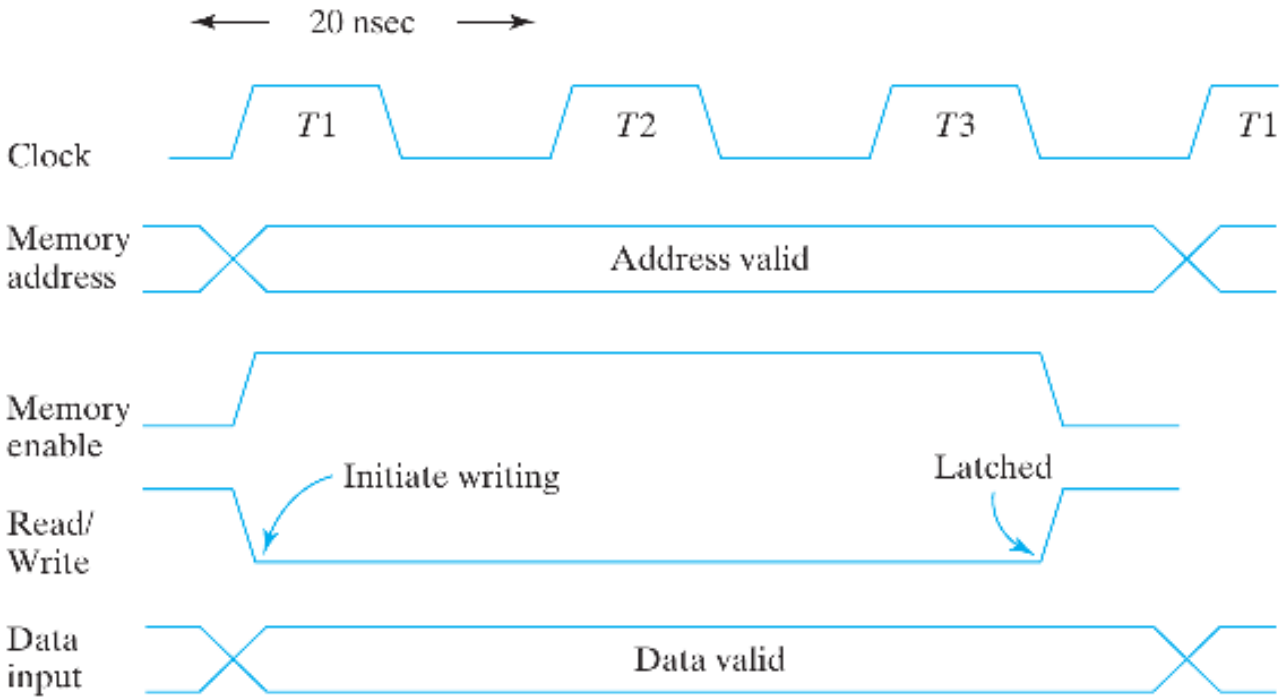


Synchronous RAMs

- We can modify the input output behaviour of the RAM array to make it synchronous
- We can easily do it using registers at appropriate points
- We can make the output *synchronous* or *flow through*
- They are all controlled using a common clock

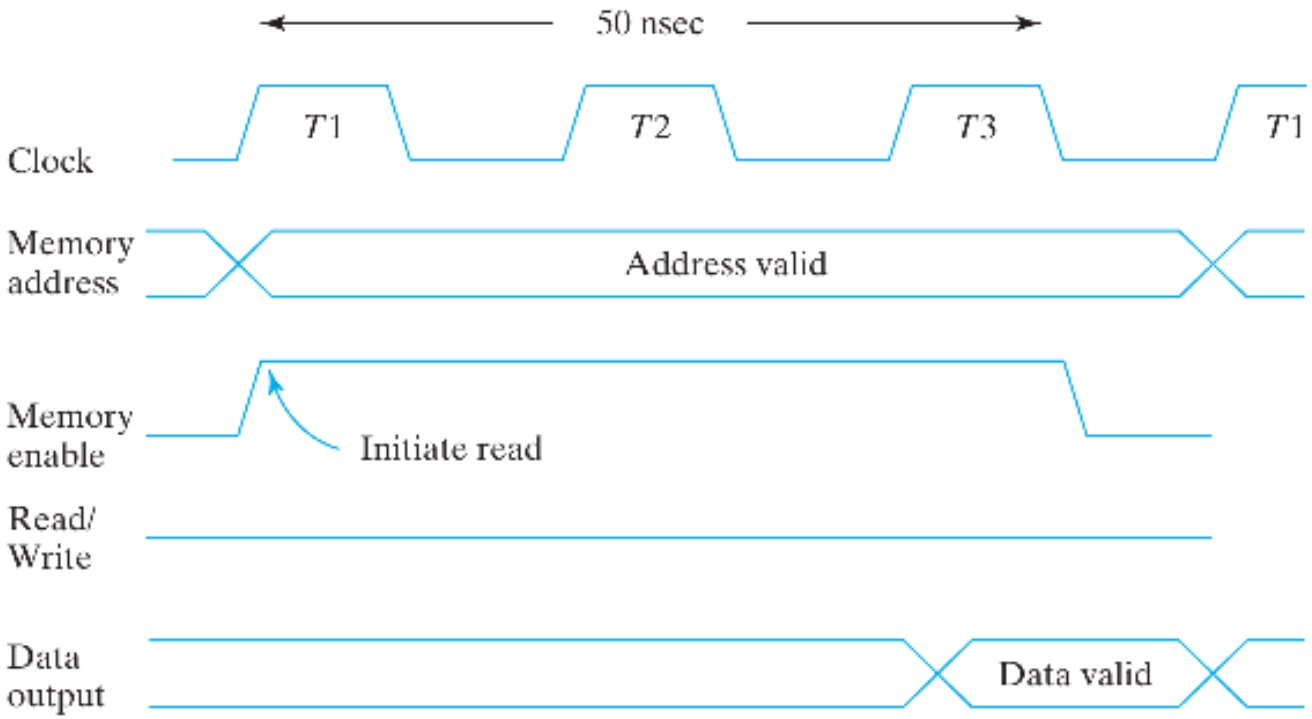


Memory read write timing



Write cycle

Memory read write timing



Read cycle