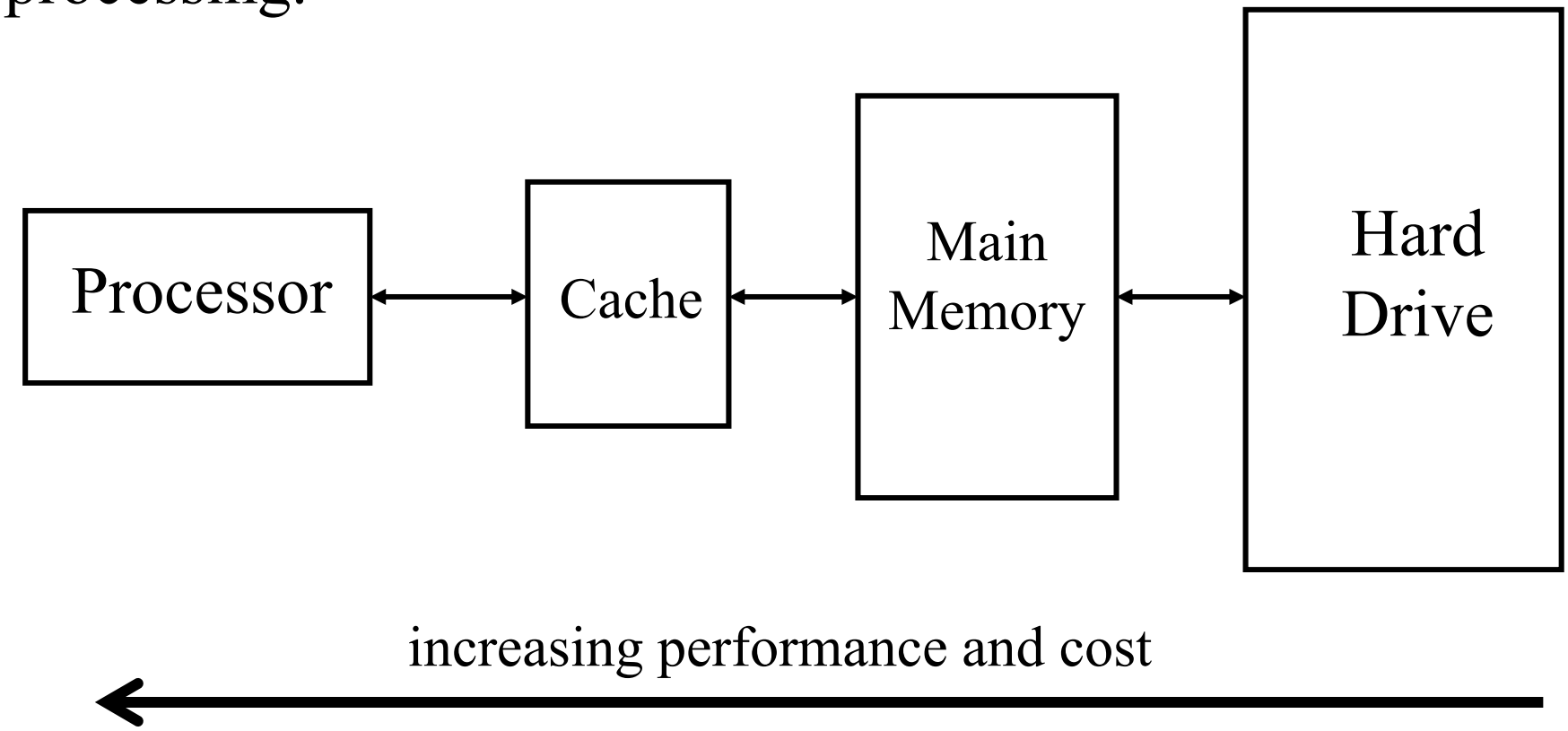
# Memory Systems

- Semiconductor Memory
- Memory Addressing
- General Storage

# Introduction

Memory is used for storing binary data, usually in large quantities. Data is held in memory, until it is required for processing.



# Units of Binary Data

An eight bit grouping of binary data is called a **byte**.

11010001, 00110011, 10101010 are all bytes of information.

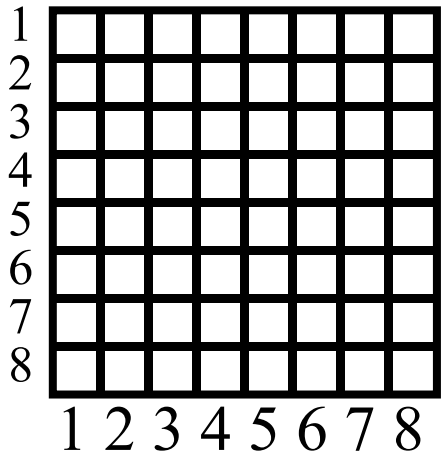
Using eight bits, 256 different numbers or codes can be represented. In general, n bits of binary data can take $2^n$ values.

A **word** is the name given to a complete unit of information and usually consists of one or more bytes. Sometimes, a four bit unit of information is referred to as a nibble.

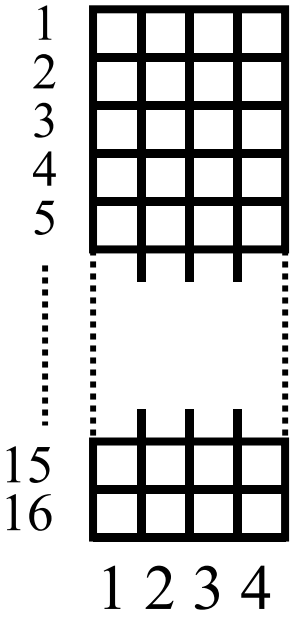
Combining two bytes to form a 16 bit word give $2^{16}$ or 65,536 different combinations.

# Semiconductor Memory

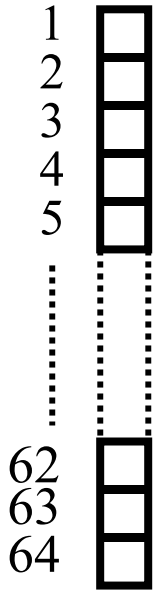
Semiconductor memory contains an array of cells that can retain a ‘0’ or a ‘1’. The cells are arranged in rows and columns. Consider the case of a 64 cell array.




8 x 8 array



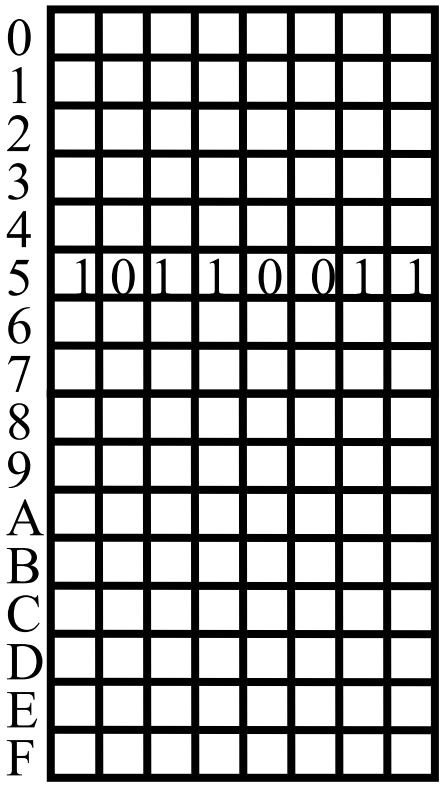

16 x 4 array




64 x 1 array

The memory is defined by the word size (number of bits in a word) and the number of words it can store. The location of each word is known as its address.

# Memory Address and Capacity




Consider the byte wide memory shown. The data byte 10110011 is at memory address 5.

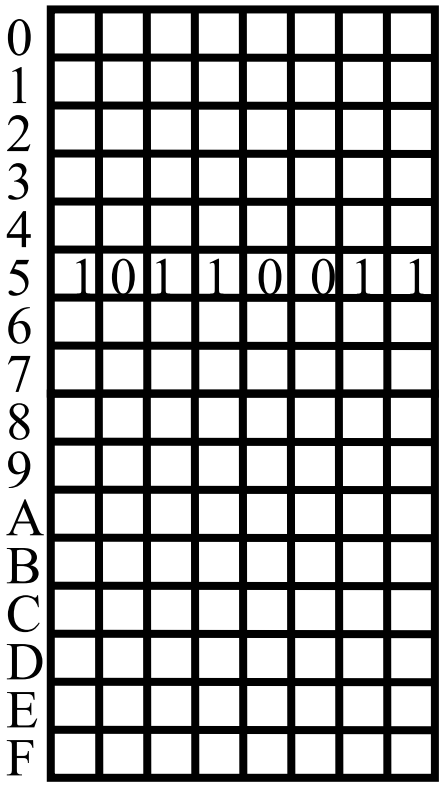
The capacity of the memory is the total number of data units that can be stored. The capacity of the memory shown is 16 bytes, which is equivalent to 128 bits.

This requires 4 address bits as $2^4 = 16$.

Prefixes may be used to indicate larger sizes
e.g 1Kbyte = 1024 bytes = 8192 bits

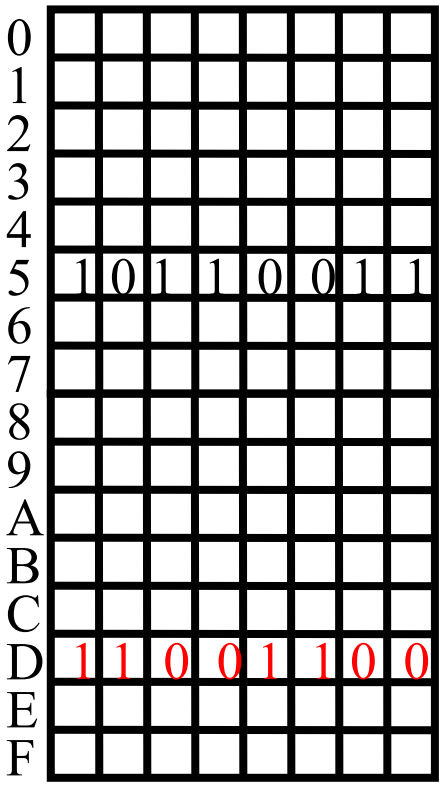
| | | |
|---|---|---|
| K = kilo $= 2^{10}$ | M = mega $= 2^{20}$ | G = giga $= 2^{30}$ |

# Memory Address and Capacity



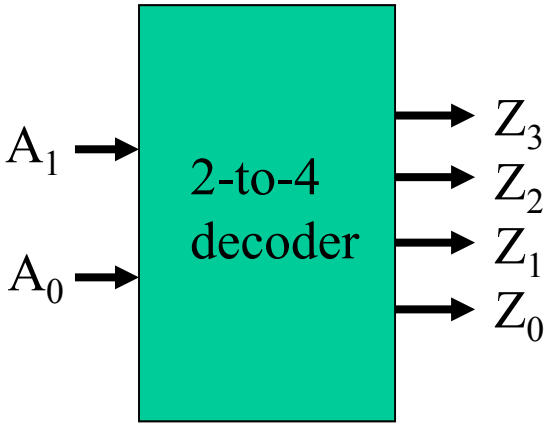

Put the byte of data 11001100 in the memory location with address D

# Memory Address and Capacity



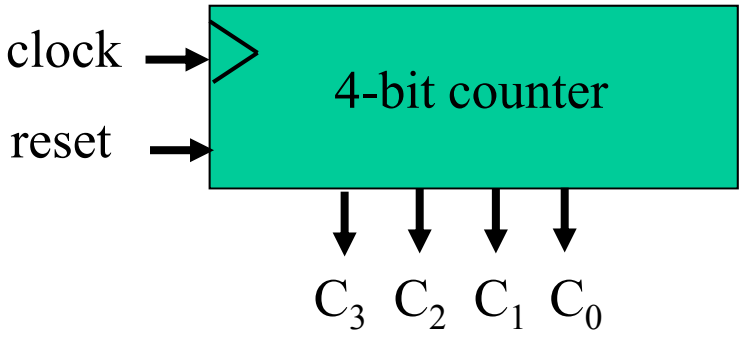

Put the byte of data 11001100 in the memory location with address D

# Decoders




| $A_1$ | $A_0$ | $Z_3$ | $Z_2$ | $Z_1$ | $Z_0$ |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 |

# Counters

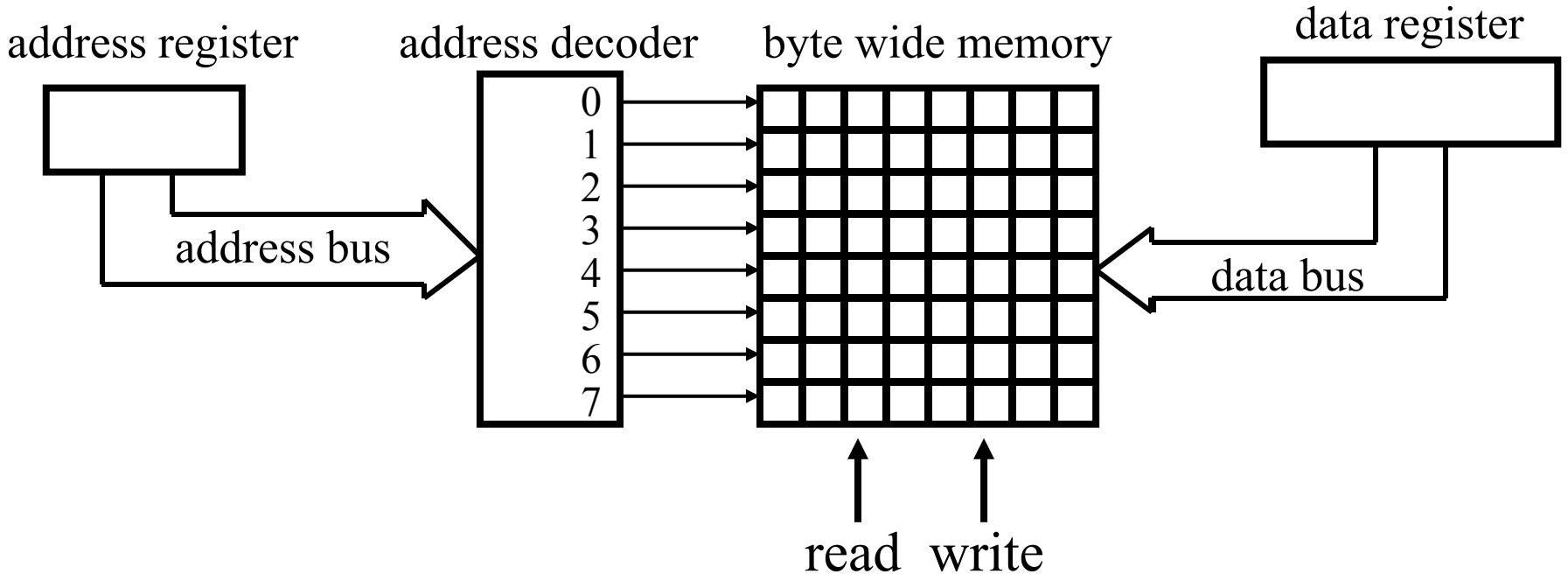



- Reset to 0000
- Increments every clock
- Can have enable
- Can be preloaded
- Can have UP/DOWN
- Useful to generate address if you need to access every memory location consecutively

| $C_3$ | $C_2$ | $C_1$ | $C_0$ |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 |

# Memory Write Operations

A write operation puts data into a specified address in the memory. The address and data go into the memory on a collection of parallel wires called a ‘bus’.




Write the byte of data 11010101 into memory location 4

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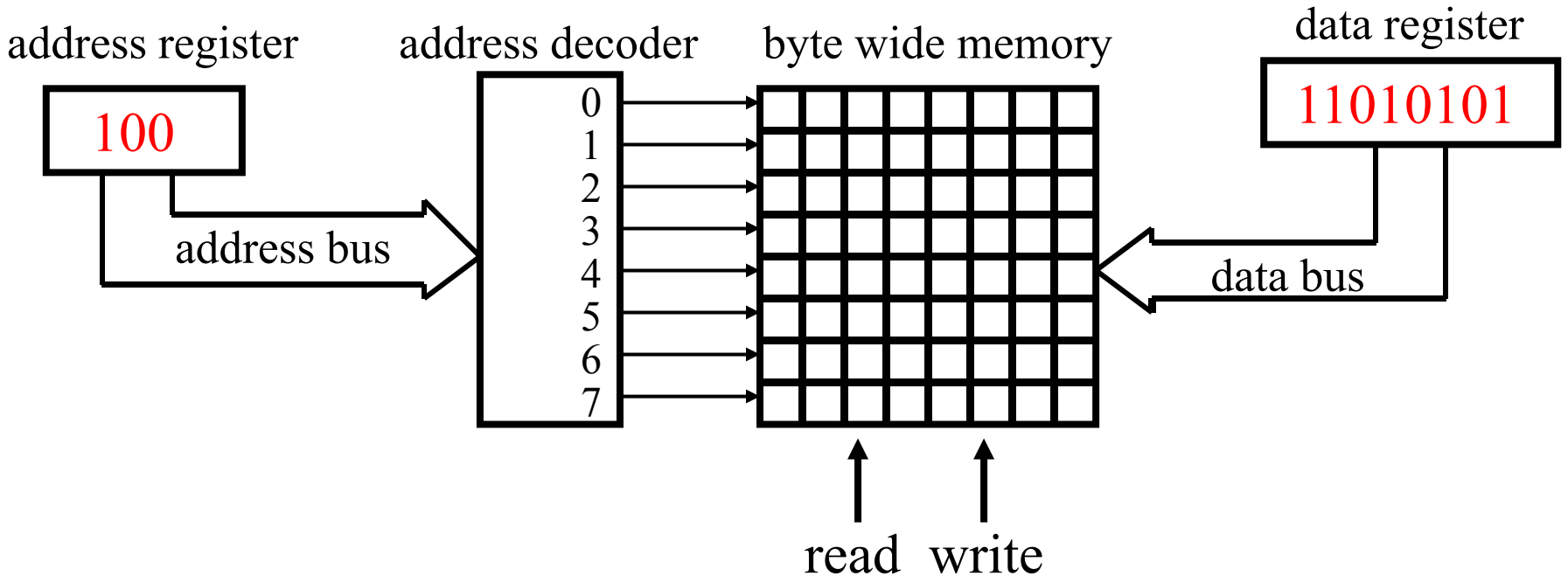


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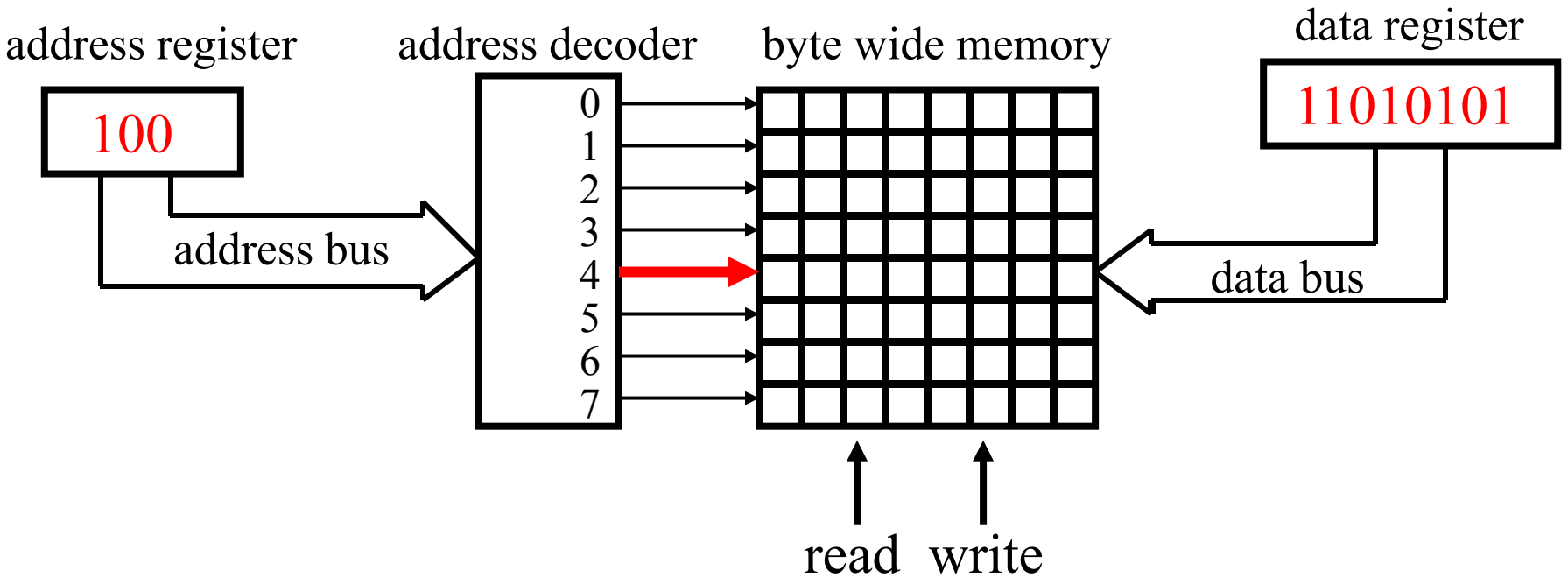


Write the byte of data 11010101 into memory location 4

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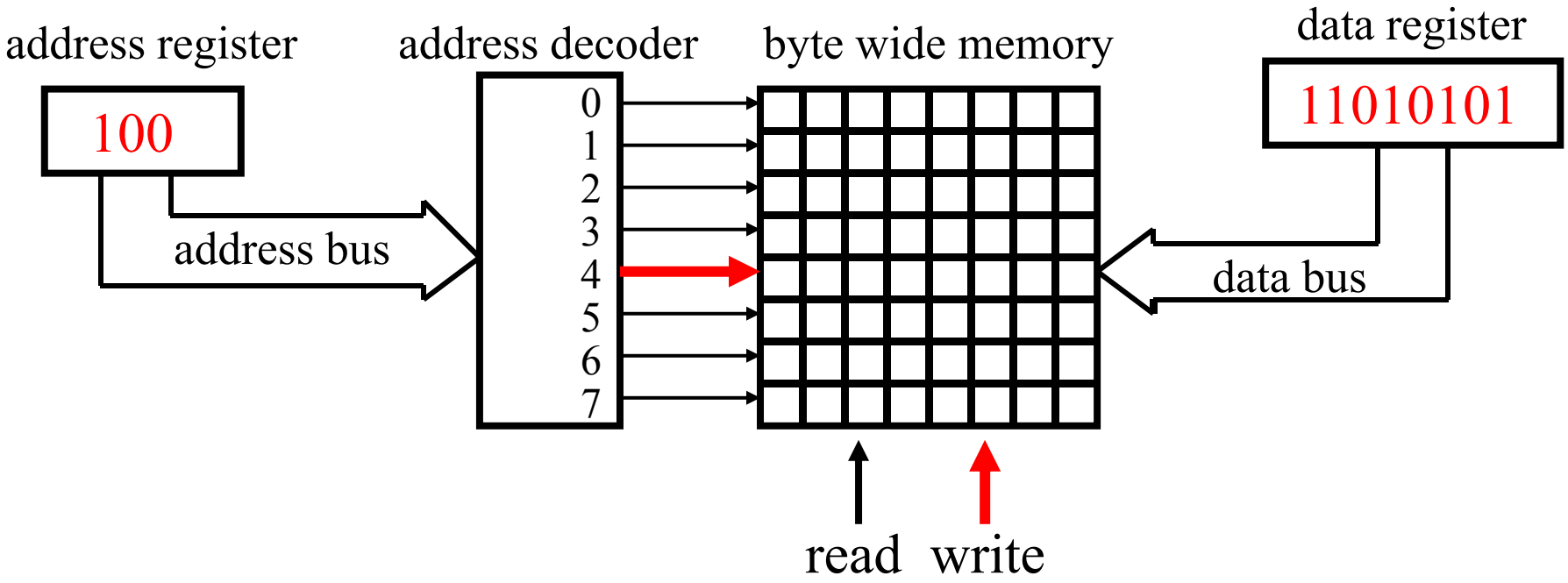


Write the byte of data 11010101 into memory location 4

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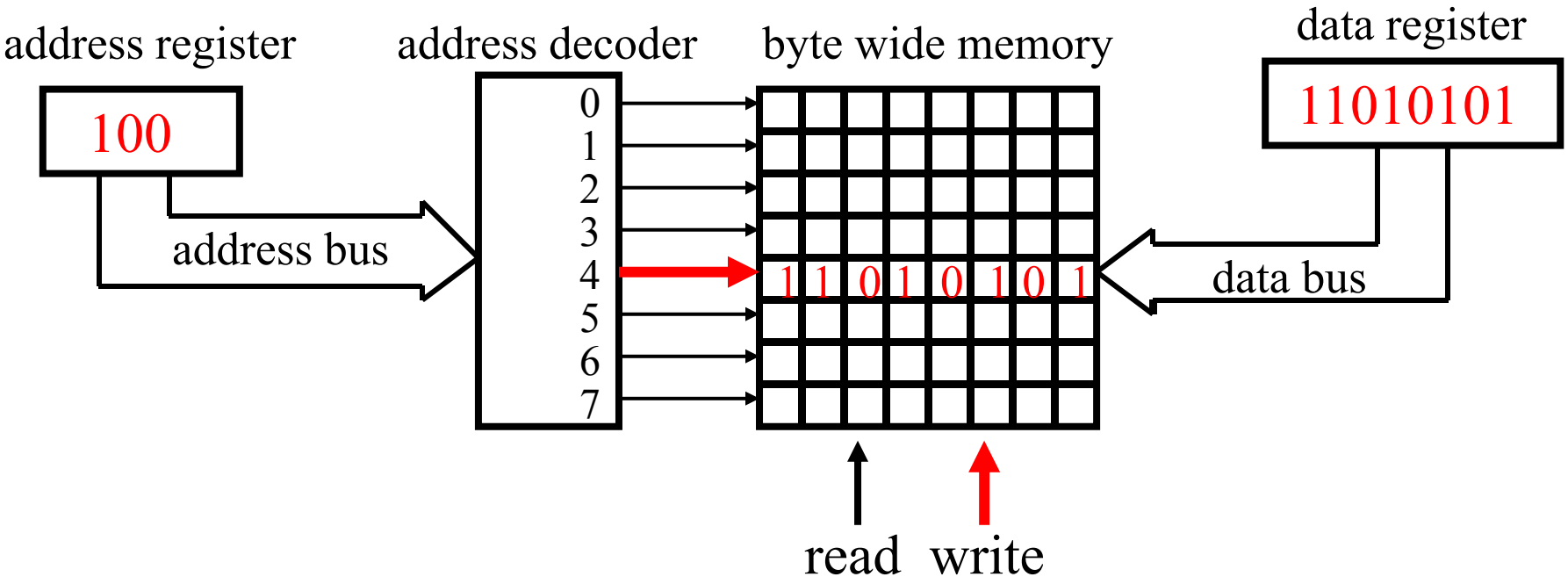


Write the byte of data 11010101 into memory location 4

# Memory Write Operations

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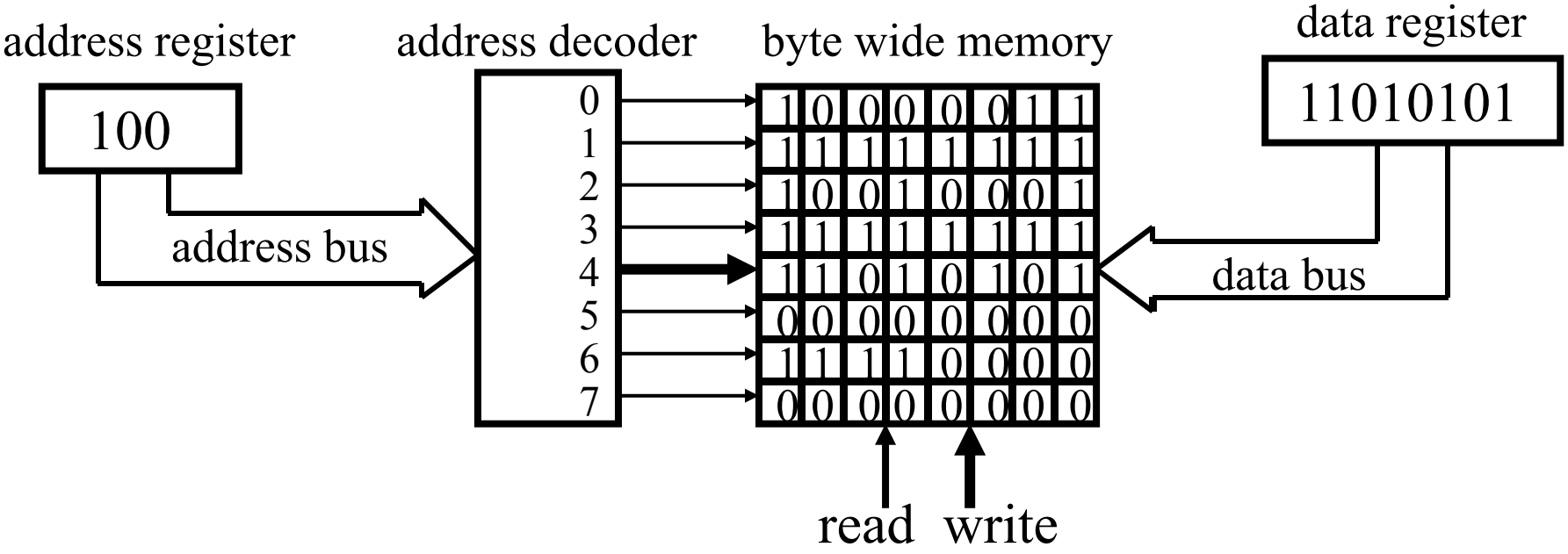
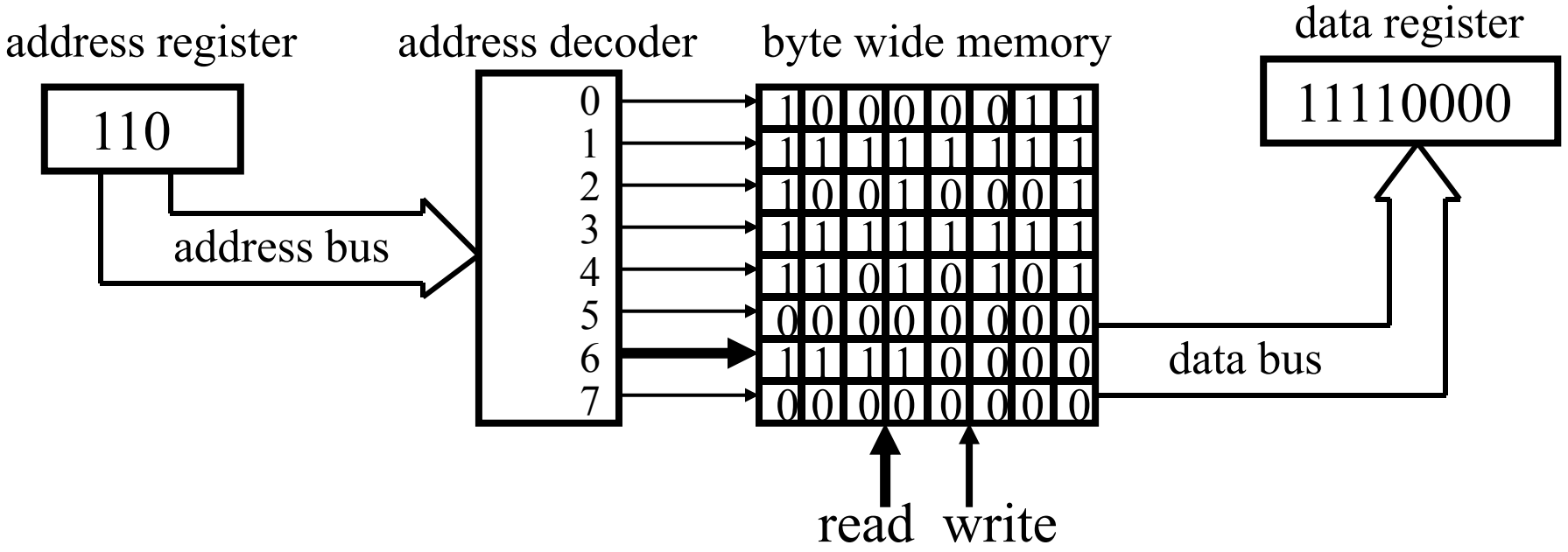



1. The address 100 is put onto the address bus.
2. The decoder decodes this address to select location four.
3. A write command on the write line causes the contents of location four to be replaced with the data currently on the data bus.

# Memory Read Operations

A read operation obtains data from a specified address in the memory. The data remains in the memory also, and is not destroyed.



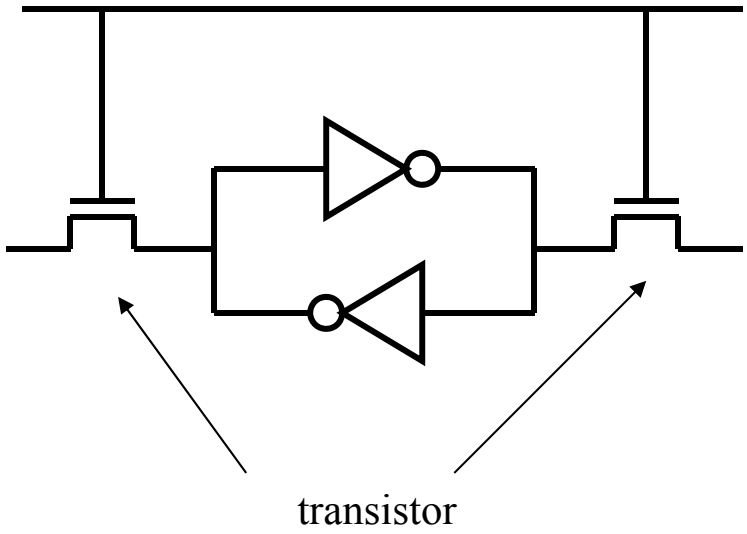

1. The address 110 is put onto the address bus.
2. The decoder decodes this address to select location six.
3. A read command on the read line causes the contents of location six to be placed on the data bus. It can then be clocked into the register.

# Random Access Memories (RAM)

RAM is a type of memory where all addresses are accessible in any order for a read or write operation. If the power to the memory is turned off, it loses its information. This is known as volatile memory. There are basically two types of RAM.

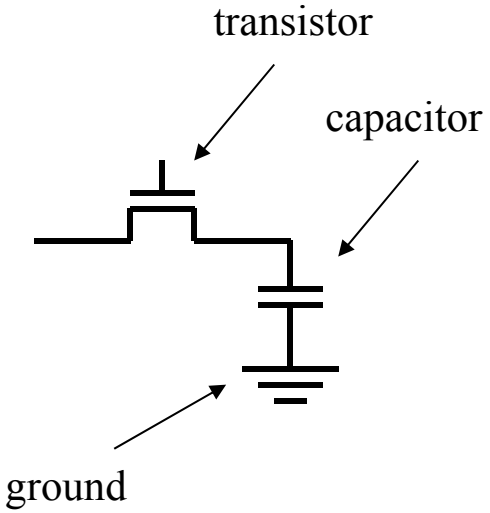
## **SRAM** (Static RAM)

This is basically a flip-flop storage cell made from several transistors. As long as power is applied, a ‘1’ or ‘0’ can be retained indefinitely.



# **DRAM** (Dynamic RAM)

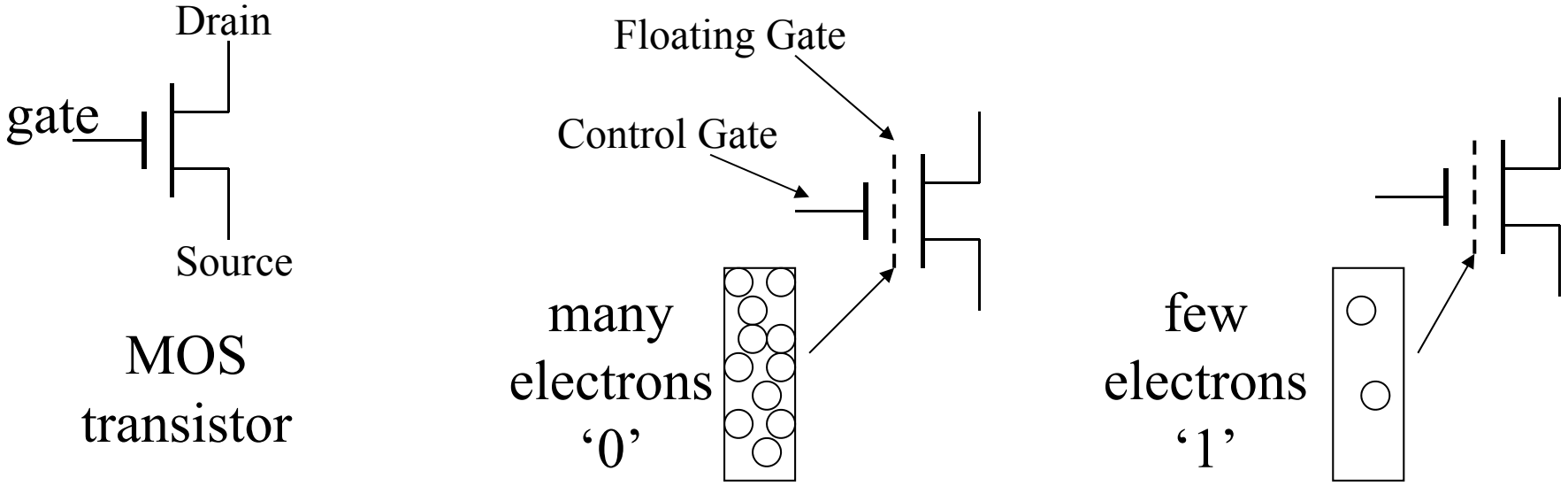
DRAM cells store data on small capacitors. This is very simple, but the storage capacitor loses its charge over time and must be periodically refreshed.




Data can be read much faster from SRAM than for DRAM. However, DRAM can store much more data for a given physical area and cost because the DRAM cell is much simpler and smaller.

# FLASH MEMORIES

Flash memory exhibits all of the qualities of an ideal memory. It is high density, read/write, and nonvolatile. The storage cell consists of a single MOS transistor with a floating gate. A data bit is stored as charge or the absence of charge on the floating gate.




The floating gate stores electrons (charge) as a result of a sufficient voltage applied to the control gate. The cell can retain charge for up to 100 years without any external power. The cell can be erased by the removal of charge.

# Mass Storage

Several types of media are available for mass nonvolatile storage of data and programs.

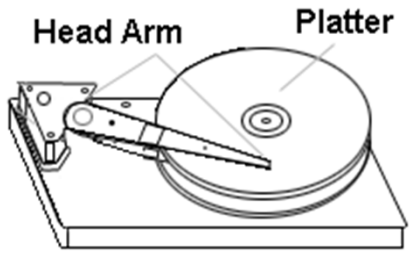
Portable mass storage uses flash memory. This is the type of memory found in music players and cameras.

Computers use magnetic hard disks for their internal mass storage.

DVDs use optical storage mainly for video and music.

# Magnetic Disk Storage

Hard Disks are rigid platters with a magnetic coating. They are stacked on top of each other and rotate on a shaft at several thousand rpm.




This is a **random access** device. Data can be stored and retrieved anywhere on the disk, in any order. The write head can be positioned to magnetise a small spot of one polarity to represent binary ‘1’ and the opposite polarity to represent binary ‘0’. The magnetic read head can determine if the stored bit is a ‘1’ or ‘0’.

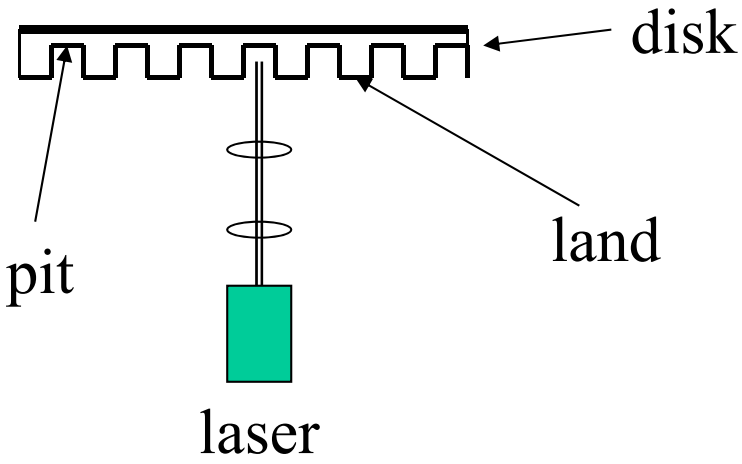
Floppy disks and magnetic tape work on the same principle and are removable. Tape is slower because data is accessed serially.

# Optical Storage

**CDROM** (Compact Disk - Read Only Memory).

**DVD** (Digital Versatile Disk)

Binary data is stored in the form of pits and lands. A pit is an indentation, stamped into the plastic. A land is the remaining flat area. A laser is used to read the data. Reflection from a pit is 180 degrees out of phase with reflection from a land.




**CD-R** : A laser is used to burn spots into an organic dye surface.

**CD-RW** : A laser is used to burn spots into a crystalline compound, which can be returned to its original state (erased).

# Summary

- Data can be stored on semiconductor memory
- SRAM, DRAM & Flash memory have been examined
- Mass storage is achieved using magnetic or optical disks