ENGG2020 Digital Logic and Systems

Chapter 7: Memory and Storage

The Chinese University of Hong Kong

Computer Memory

The memory capability is what makes digital systems so versatile and adaptable to many situations

Flip-Flop – an electronic memory device

Register – a group of flip-flops to store information

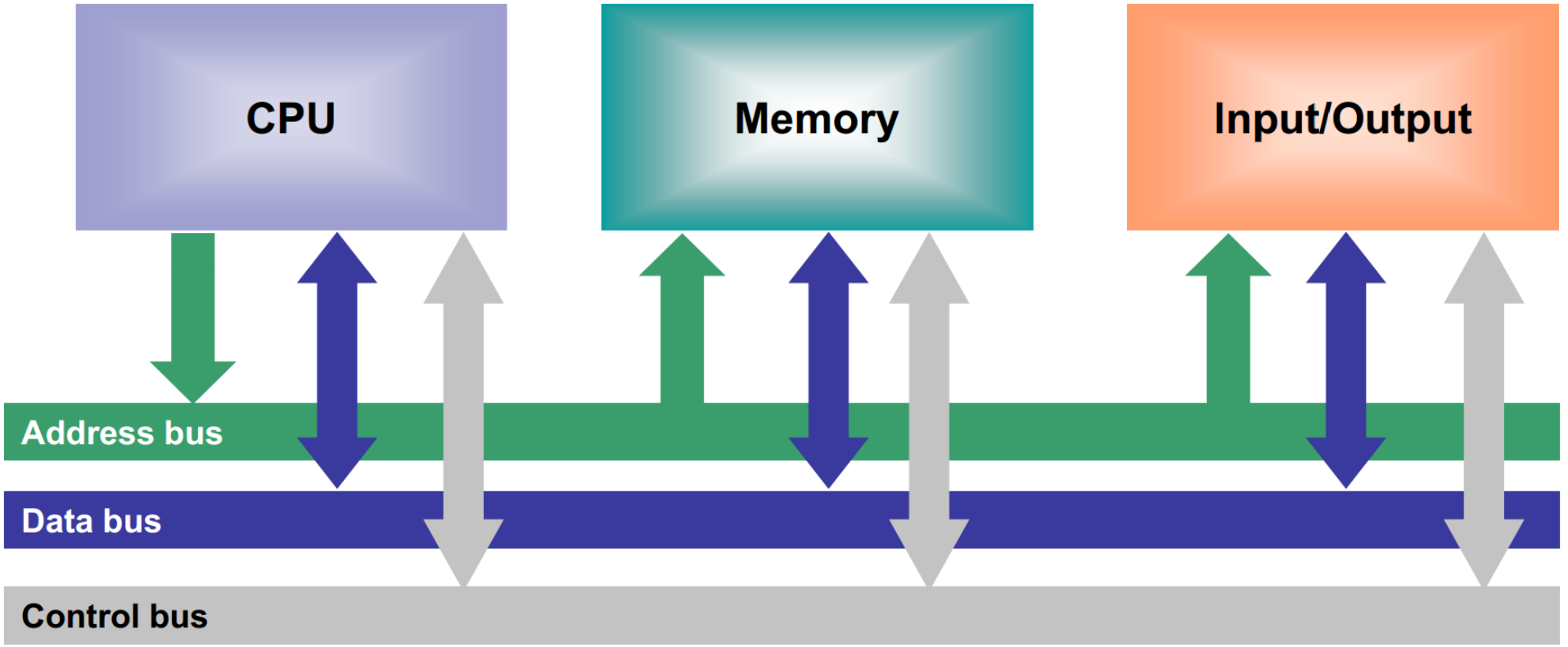
Memory Categories

Volatile or non-volatile

Semiconductor or magnetic

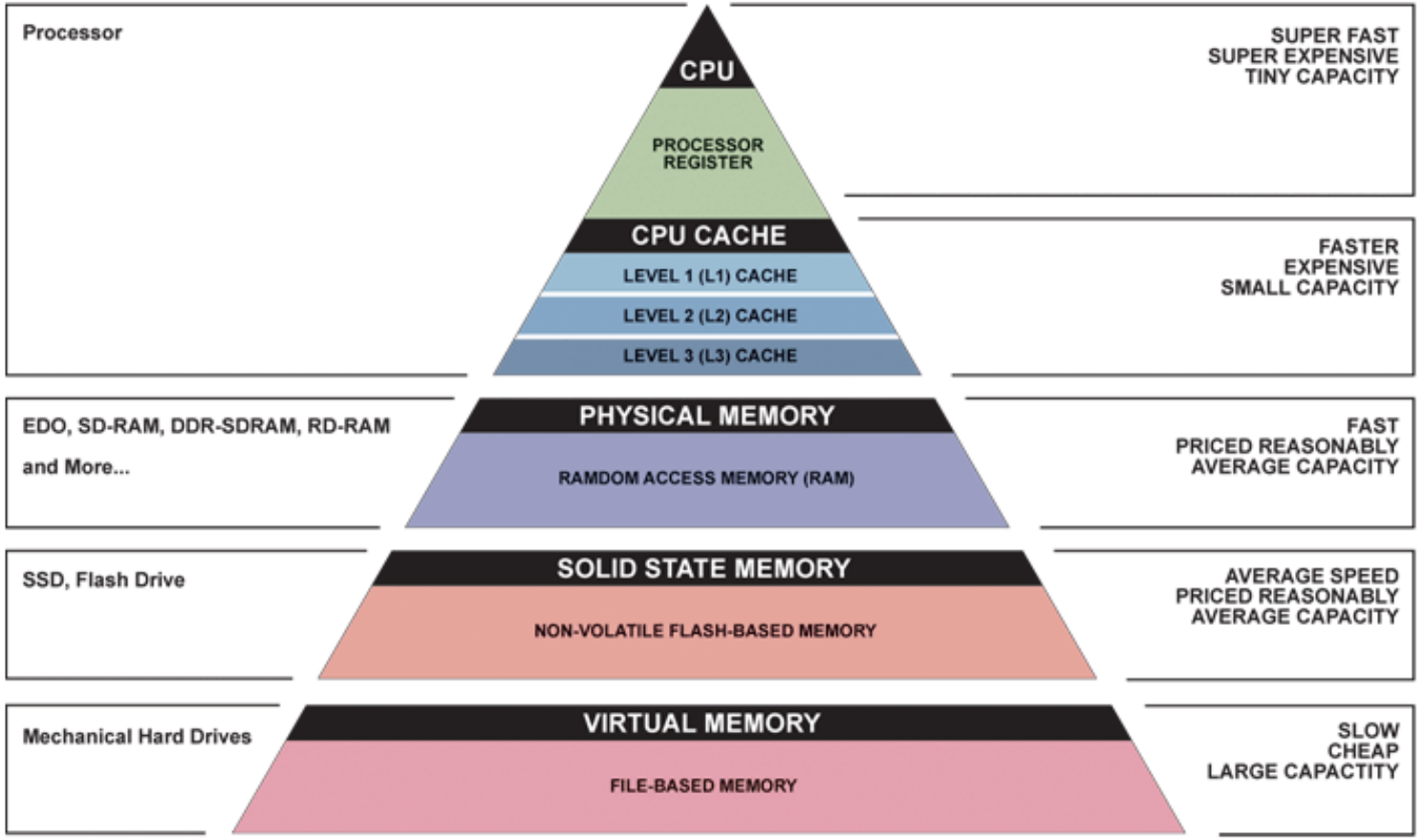
Primary memory or secondary memory

A Basic Microprocessor System



Courtesy of fke.utm.my

Computer Memory Hierarchy



▲ Simplified Computer Memory Hierarchy
Illustration: Ryan J. Leng

Courtesy of bit-tech.net

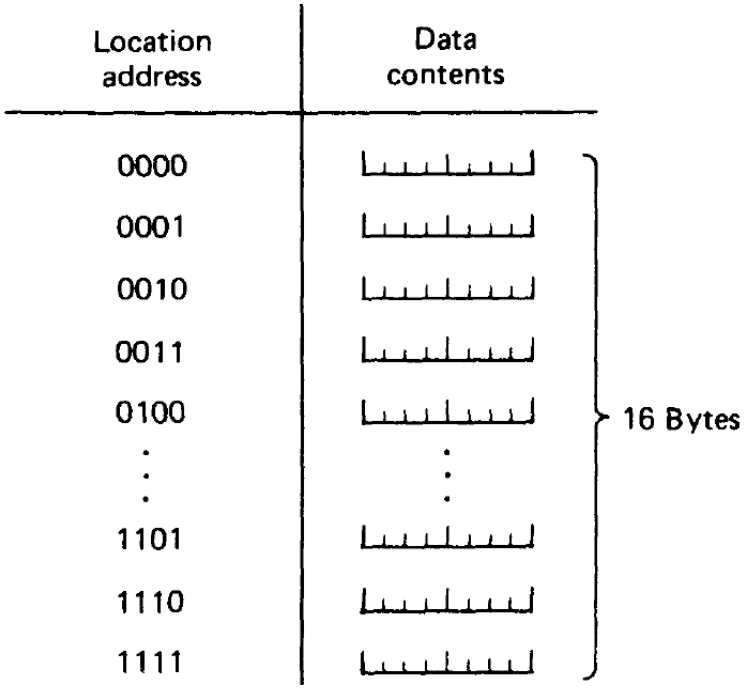
Basic Concept

Assume a device with 8 binary switches and the states of the switches will be stored every one hour from 0700 to 2200 inclusively

What is the size of memory to store these information?

16 memory locations are required i.e. 4-bit address

Each location is capable of containing 1 byte (8-bits) data



Basic Concept

The number of memory words can be stored depends on the size of the address bus

4-bits address bus means 16 locations (2^4) for storage

1K = 1024 (2^{10}) not 1000

The data size depends on the size of data bus

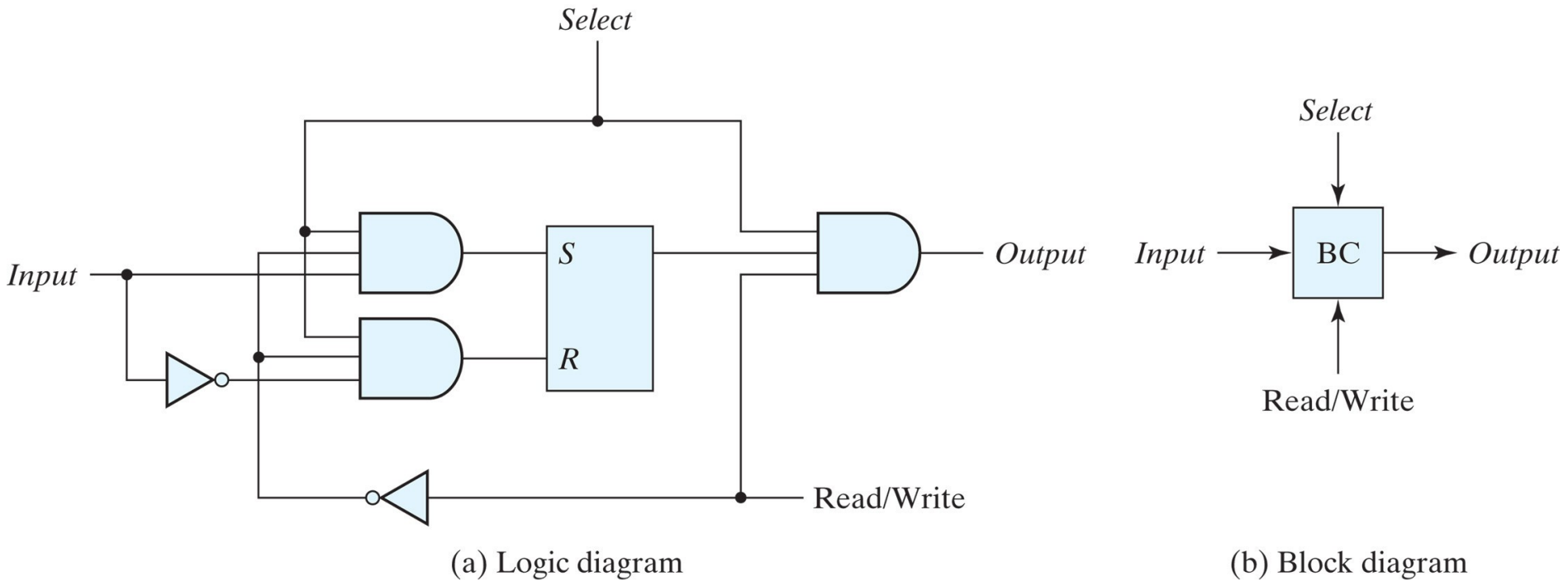
8-bits data bus means the size of memory words is 8-bits

Total capacity of the memory is number of memory words times data size

4K x 16 = 4 x 1024 x 16 = 65536 bits

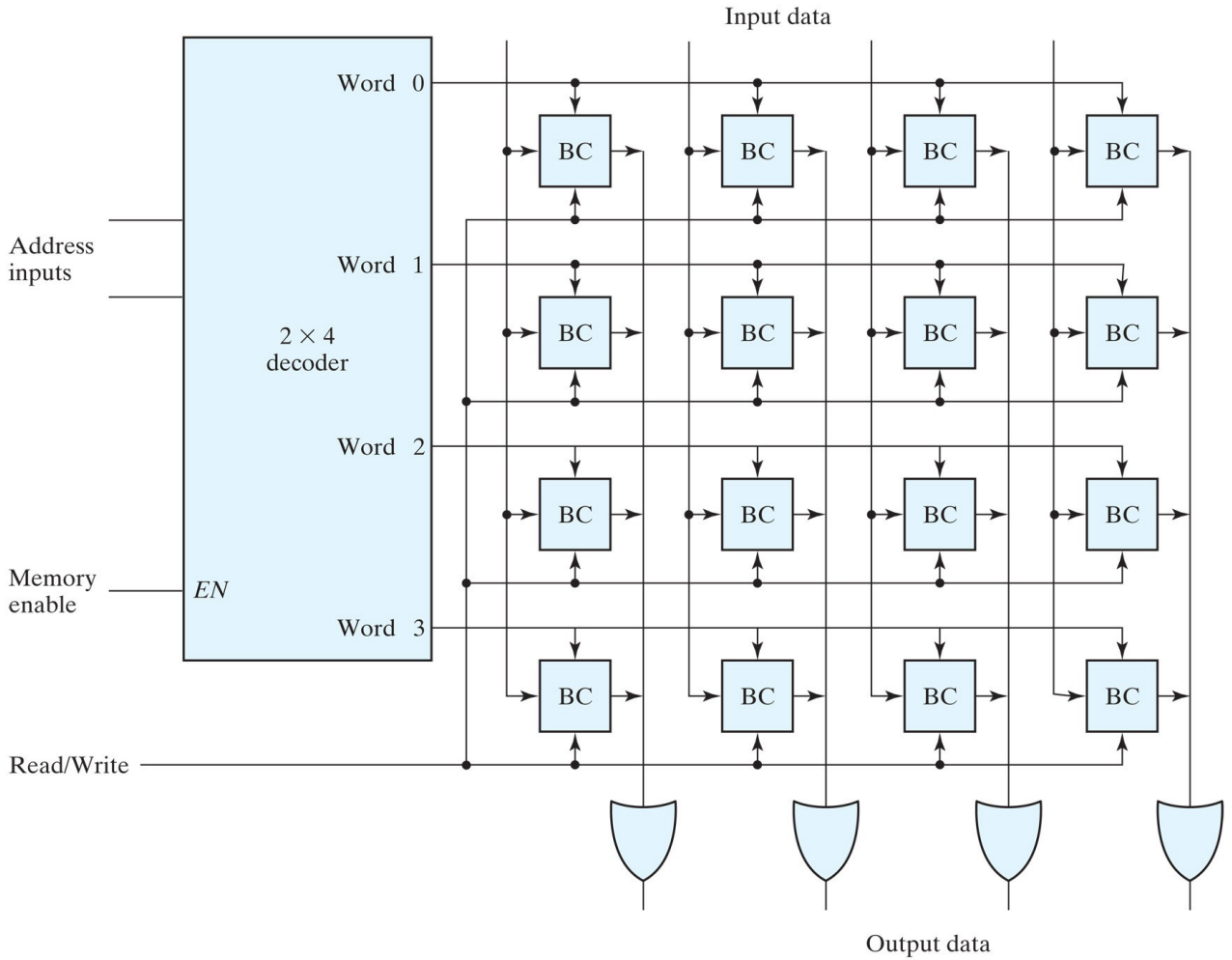
Basic Concept

Memory cell



Basic Concept

Diagram of a 4 × 4 RAM



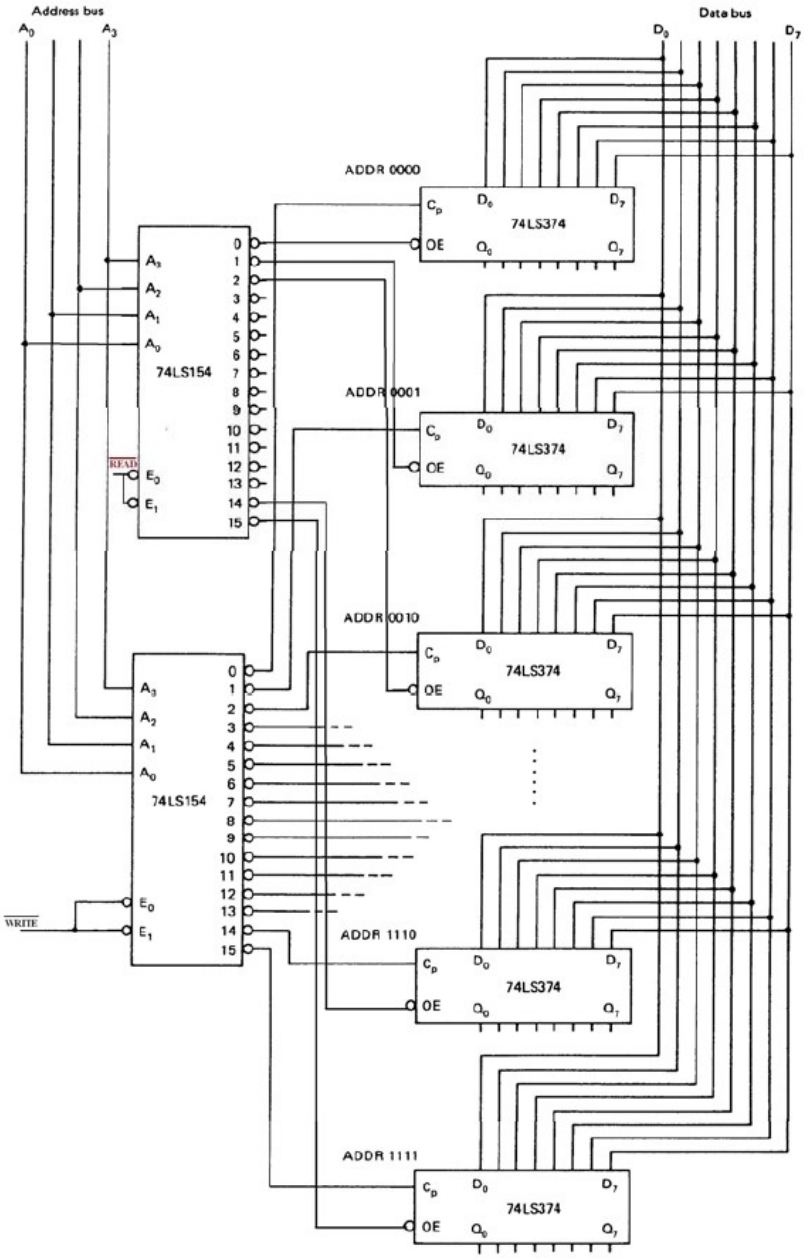
Basic Concept

74LS374 is octal D flip-flop with three-state outputs to store the data

Rising edge on the clock input will latch the data into flip-flop

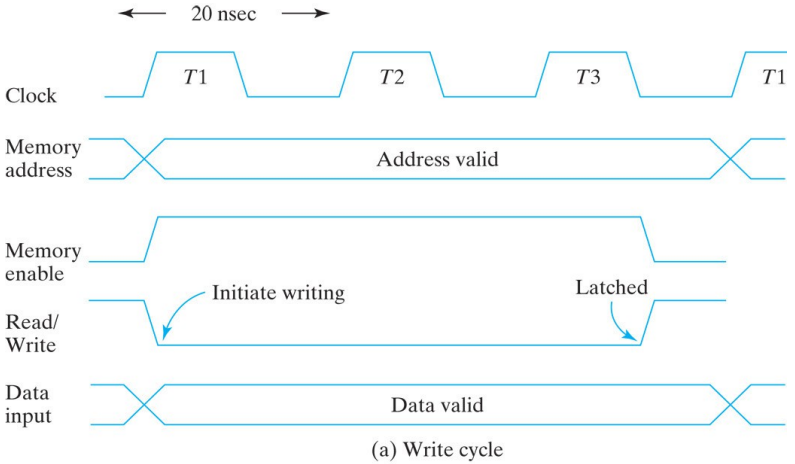
Output Enable pin is LOW to get the value stored in the D flip-flop

74LS154 is a 4-Line to 16-Line Decoder/Demultiplexer to select the appropriate memory location for input/output

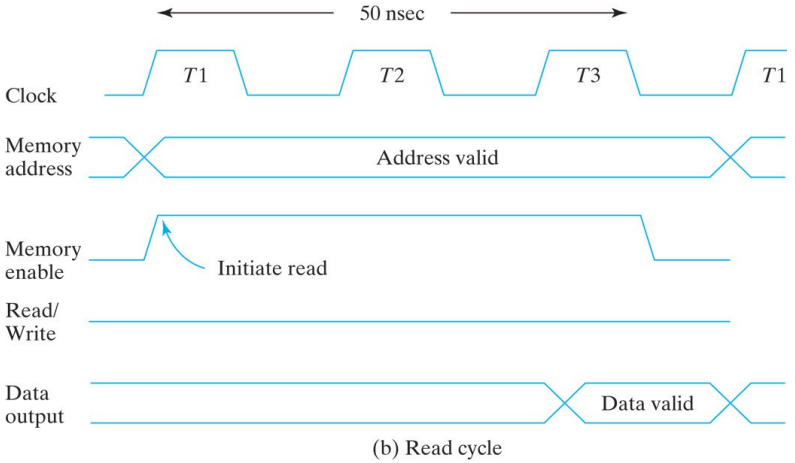


Basic Concept

Memory cycle timing waveforms



(a) Write cycle



(b) Read cycle

Random Access Memory (RAM)

RAM is used for temporary storage of data and program instructions in microprocessor-based systems

Random Access means the user can access data at any location within the entire memory device randomly

Categories

Static RAMs (SRAMs)

Dynamics RAMs (DRAMs)

Random Access Memory (RAM)

SRAMs

Use flip-flops as basic storage elements

Data is held as long as the power supply is not cut off

Faster

Lower power consumption

Simpler

6 transistors for 1 memory cell =>Bulky and Higher price

DRAMs

Use internal capacitors as basic storage elements

Additional circuitry is required to refresh the data for retaining purpose

Slower

Higher power used

1 transistor and 1 capacitor => Dense and Lower price

Commonly used in main memory

Read Only Memory (ROM)

Capable of random access

Nonvolatile i.e. do not lose their memory contents when power is removed

- BIOS (Basic Input Output System)
- Firmware, which is a software that tied to specific hardware

Mask ROM

- Fabricated with the desired data permanently stored in it by manufacturer
- Unique mask is required in the fabrication

Read Only Memory (ROM)

User-Programmable ROM (PROM)

Avoid the high one-time cost of producing a custom mask (Mask ROM)

EPROM (Erasable PROM)

Use UV light source to erase the stored data

EEPROM or E2PROM (Electrically Erasable PROM)

Use high voltage to erase the chip

Tuner of a modern TV set

Read Only Memory (ROM)

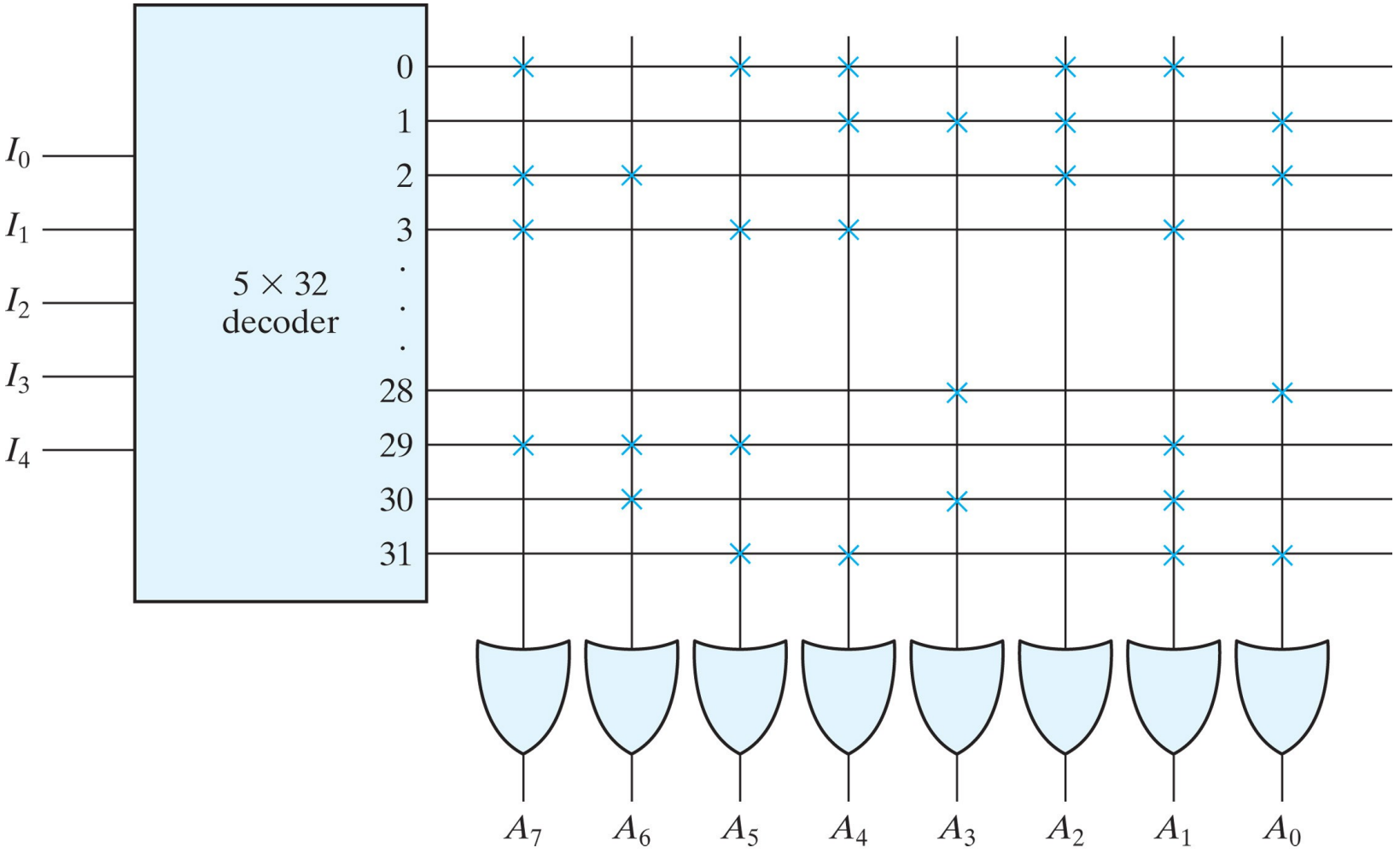
Example: ROM Truth Table (Partial)

Table 7.3
ROM Truth Table (Partial)

Inputs					Outputs							
I_4	I_3	I_2	I_1	I_0	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0
0	0	0	0	0	1	0	1	1	0	1	1	0
0	0	0	0	1	0	0	0	1	1	1	0	1
0	0	0	1	0	1	1	0	0	0	1	0	1
0	0	0	1	1	1	0	1	1	0	0	1	0
		⋮							⋮			
1	1	1	0	0	0	0	0	0	1	0	0	1
1	1	1	0	1	1	1	1	0	0	0	1	0
1	1	1	1	0	0	1	0	0	1	0	1	0
1	1	1	1	1	0	0	1	1	0	0	1	1

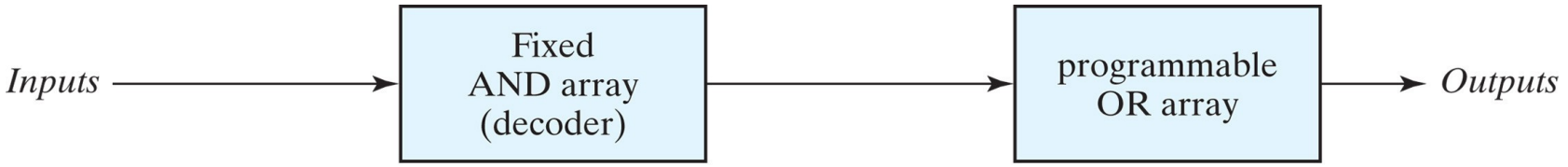
Read Only Memory (ROM)

Programming the ROM according to Table 7.3



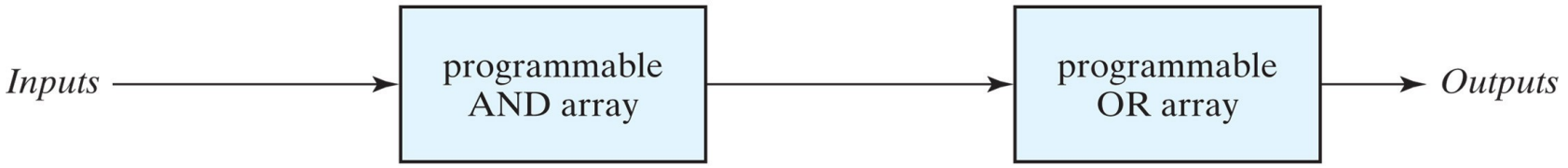
Read Only Memory (ROM)

Basic configuration of three PLDs



(a) Programmable read-only memory (PROM)

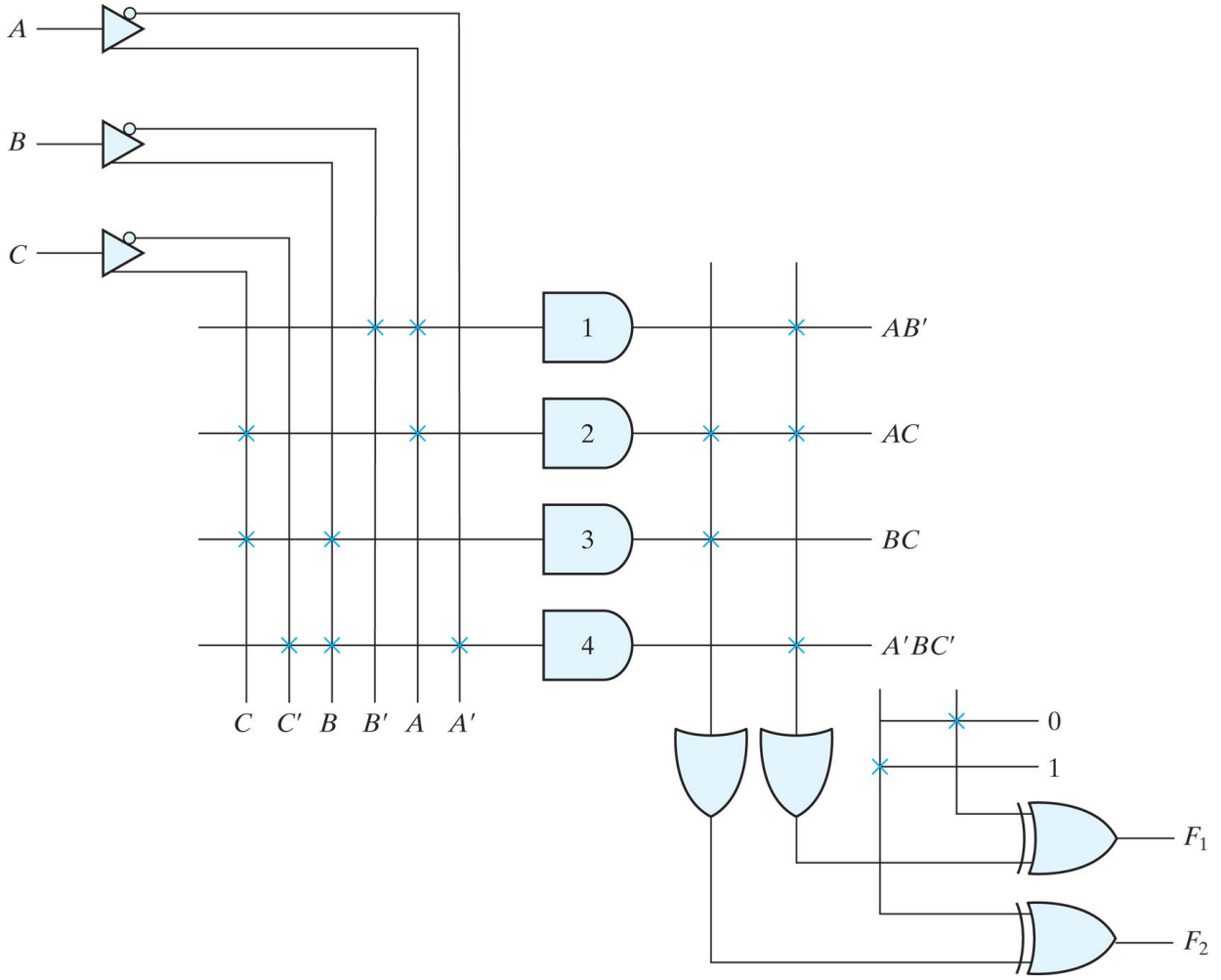
(b) Programmable array logic (PAL)



(c) Programmable logic array (PLA)

Read Only Memory (ROM)

PLA with three inputs, four product terms, and two outputs



Memory Expansion

Expand the Size (e.g. 8-bit to 32-bit)

Connect ICs in parallel

Share all control and address signals

Data In/Out signals are independent

Expand the Locations (e.g. 4K to 16K)

Connect ICs in series

Share all control signals and Data In/Out signals (i.e. share the same data bus)

Share part of address signals (start from LSB) and the remaining address signals are used for IC selection

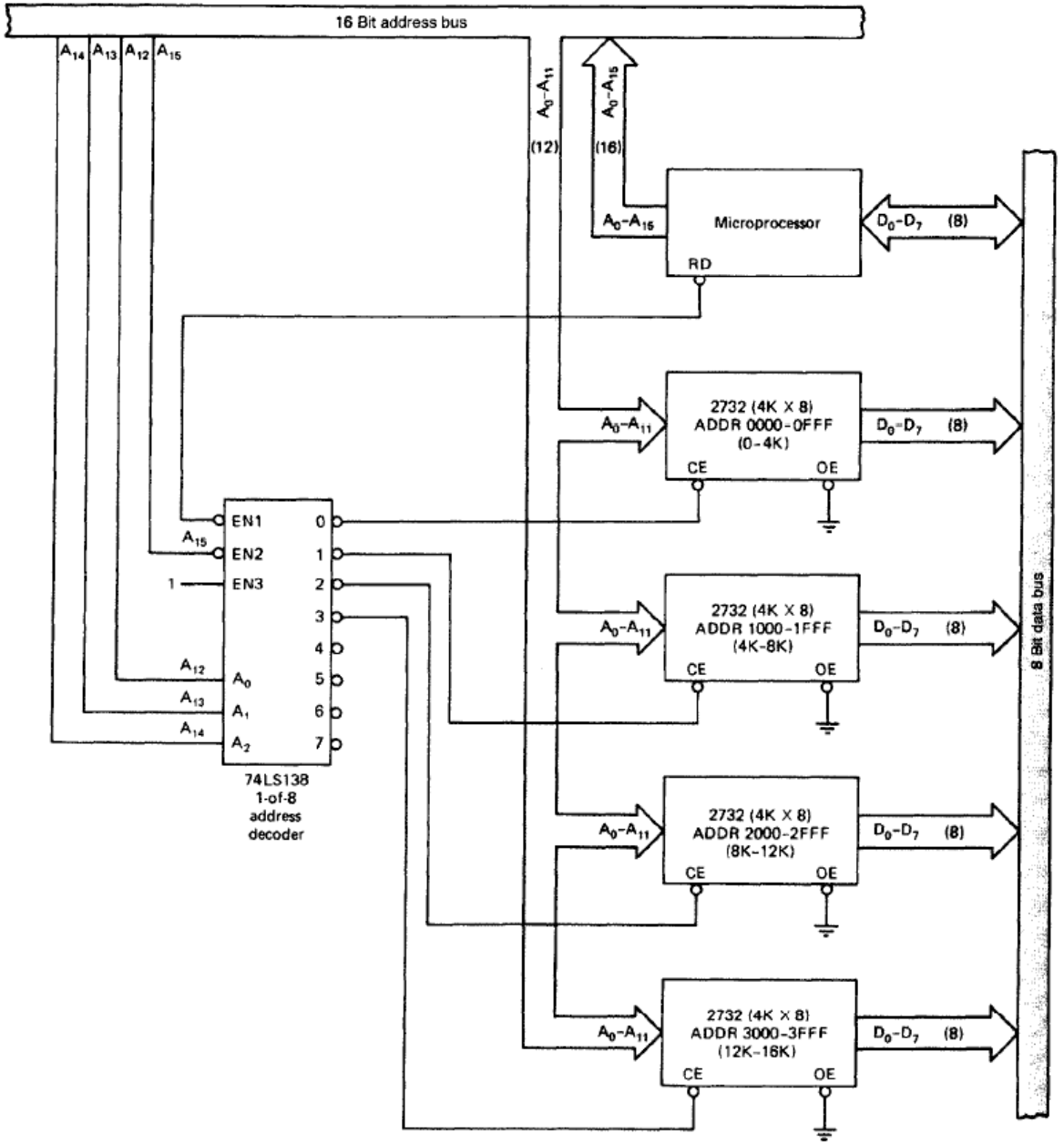
Memory Expansion

Use to identify which IC (if the circuit has more than one IC) is to be read or written to

In this configuration, only 16K addresses are used

- The system is active when A15-12 = 0000 to 0011
- Not all outputs from the decoder are used
- Simple changes can be made to expand the memory

Memory Expansion



Magnetic and Optical Storage

Magnetic and optical memories are electromechanical in nature

Memory materials containing “1”s and “0”s physically spins beneath a read/write head

Non-volatile: no loss of data when power is off

Due to the sequential nature, we are concern about the

- Average access time (depends on the spinning speed and number of heads)
- Worst access time
- Data transfer rate

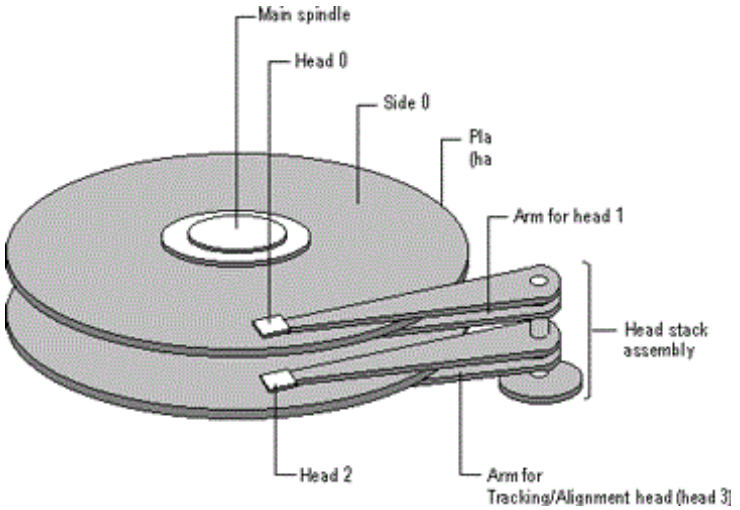
Magnetic and Optical Storage

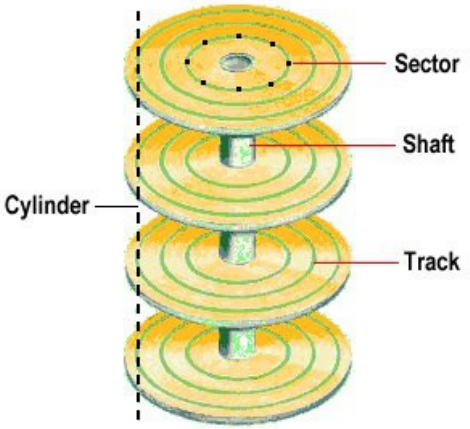
Magnetic Memory

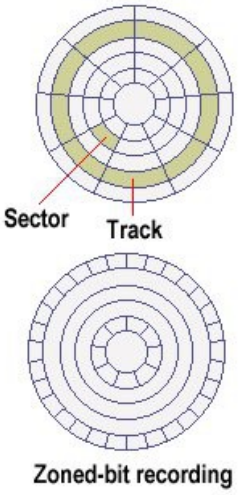
1”s and “0”s are represented on the magnetic medium as a tiny North-south or south-north magnet

Write: magnetise the medium into a particular orientation

Read: detect the direction of the induced voltage when the tiny magnet passes the read/write head







Magnetic and Optical Storage

Optical Memory

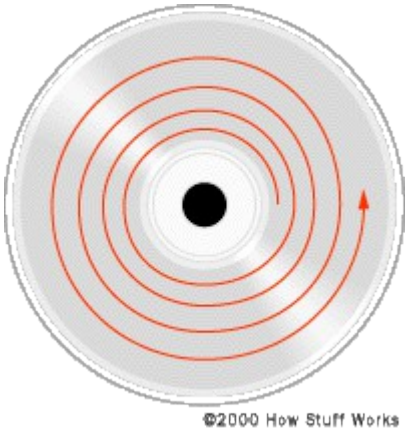
Aluminium alloy coating on a rigid polycarbonate wafer

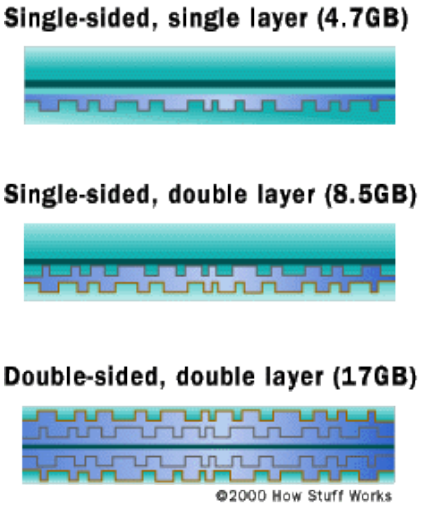
“1”s and “0”s are represented on the medium as existence of an indentation (pits) or absence of the indentation (land)

Write operation

Print the required data during mass manufacturing. (e.g. Music CD)

Use Laser beam to burn the pits on blank CD (e.g. CD ROM)





Flash Memory

A special type of memory that works like both RAM and ROM

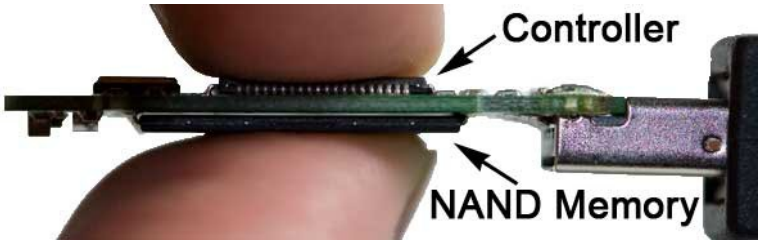
- Can write information to flash memory
- Information is kept when the power is off

Developed from EEPROM

Two main types of flash memory

NAND type

- Written and read in blocks



Courtesy of recovermyflashdrive.com

NOR type

- Written and read in a single machine word