Introduction

- There are two types of memories that are used in digital systems:

  Random-access memory(RAM): perform both the write and read operations.

  Read-only memory(ROM): perform only the read operation.

- The read-only memory is a programmable logic device. Other such units are the programmable logic array(PLA), the programmable array logic(PAL), and the field-programmable gate array(FPGA).

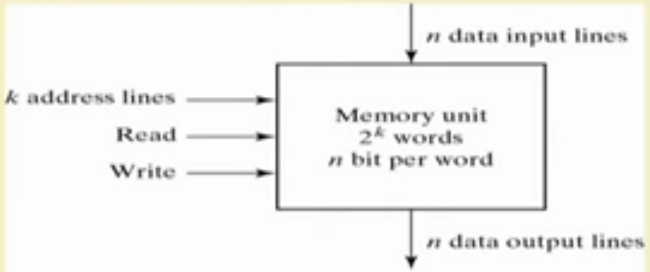
Random-Access Memory

- A memory unit stores binary information in groups of bits called words.

  1 byte = 8 bits

  1 word = 2 bytes (or more)

- The communication between a memory and its environment is achieved through data input and output lines, address selection lines, and control lines that specify the direction of transfer.



Block Diagram of a Memory Unit

Content of a memory

- Each word in memory is assigned an identification number, called an address, starting from 0 up to 2^k-1, where k is the number of address lines.
- The number of words in a memory with one of the letters $K=2^{10}$, $M=2^{20}$, or $G=2^{30}$.

$64K = 2^{16}$ $2M = 2^{21}$ $4G = 2^{32}$

Memory address		
Binary	decimal	Memory content
0000000000	0	1011010101011101
0000000001	1	1010101110001001
0000000010	2	0000110101000110
⋮	⋮	⋮
1111111101	1021	1001110100010100
1111111110	1022	0000110100011110
1111111111	1023	1101111000100101

Content of a 1024 × 16 Memory

Write and Read operations

- Transferring a new word to be stored into memory:

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

Write and Read operations

- Transferring a stored word out of memory:

1. Apply the binary address of the desired word to the address lines.
2. Activate the read input.

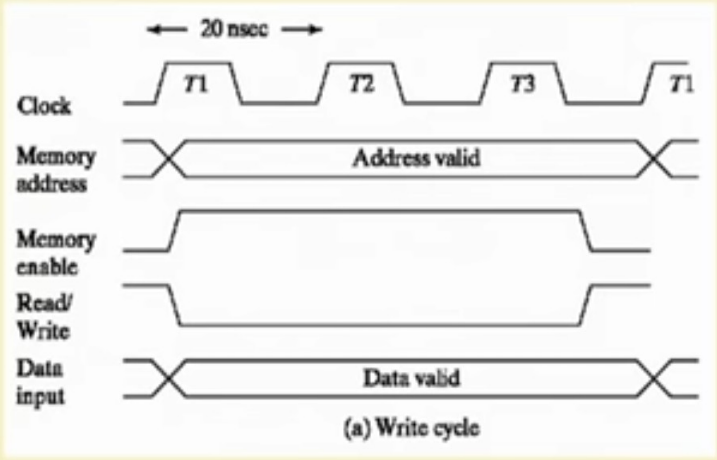
- Commercial memory sometimes provide the two control inputs for reading and writing in a somewhat different configuration.

Control Inputs to Memory Chip

Memory Enable	Read/Write	Memory Operation
0	X	None
1	0	Write to selected word
1	1	Read from selected word

Timing Waveforms (write)

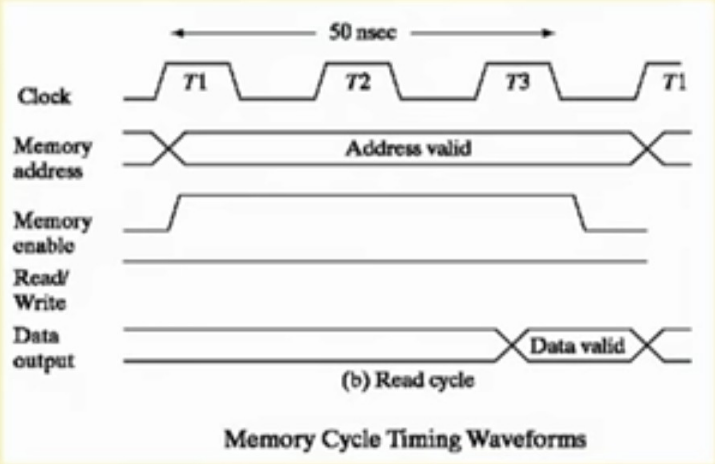
- The access time and cycle time of the memory must be within a time equal to a fixed number of CPU clock cycles.
- The memory enable and the read/write signals must be activated after the signals in the address lines are stable to avoid destroying data in other memory words.
- Enable and read/write signals must stay active for at least 50ns.



(a) Write cycle

Timing Waveforms (read)

- The CPU can transfer the data into one of its internal registers during the negative transition of T3.



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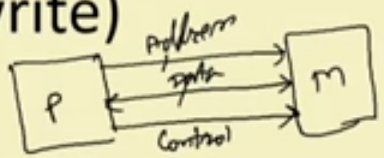

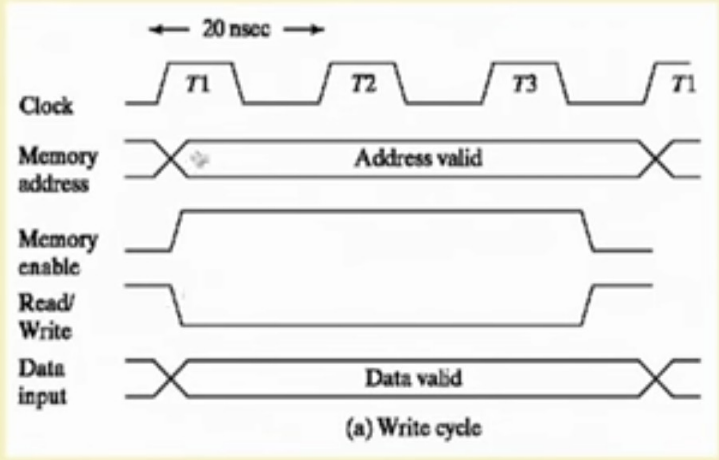

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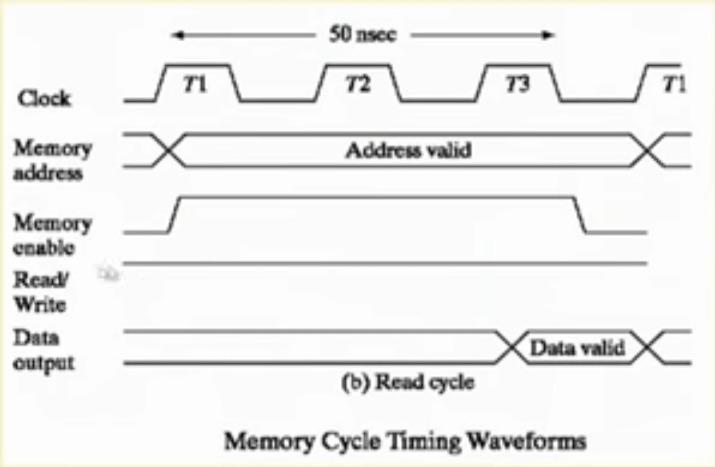


Memory Cycle Timing Waveforms

Types of memories

- In random-access memory, the word locations may be thought of as being separated in space, with each word occupying one particular location.
- In sequential-access memory, the information stored in some medium is not immediately accessible, but is available only certain intervals of time. A magnetic disk or tape unit is of this type.

Types of memories

- In a random-access memory, the access time is always the same regardless of the particular location of the word.
- In a sequential-access memory, the time it takes to access a word depends on the position of the word with respect to the reading head position; therefore, the access time is variable.

Static RAM

- SRAM consists essentially of internal latches that store the binary information.
- The stored information remains valid as long as power is applied to the unit.
- SRAM is easier to use and has shorter read and write cycles.
- Low density, low capacity, high cost, high speed, high power consumption.

Dynamic RAM

- DRAM stores the binary information in the form of electric charges on capacitors.
- The capacitors are provided inside the chip by MOS transistors.
- The capacitors tends to discharge with time and must be periodically recharged by refreshing the dynamic memory.

Dynamic RAM

- DRAM offers reduced power consumption and larger storage capacity in a single memory chip.
- High density, high capacity, low cost, low speed, low power consumption.

Types of memories

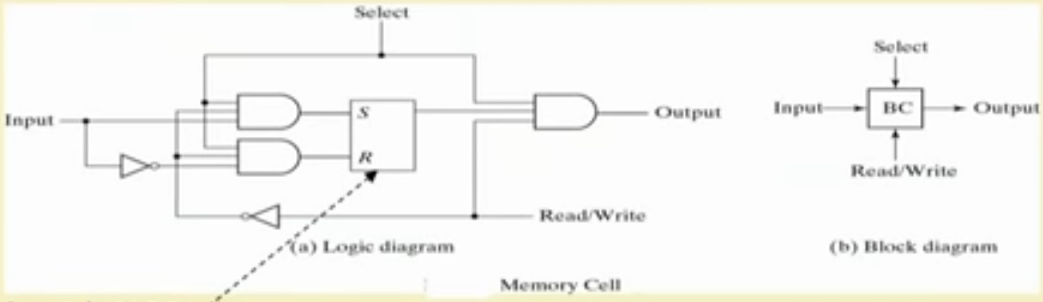
- Memory units that lose stored information when power is turned off are said to be volatile.
- Both static and dynamic, are of this category since the binary cells need external power to maintain the stored information.
- Nonvolatile memory, such as magnetic disk, ROM, retains its stored information after removal of power.

Memory decoding

- The equivalent logic of a binary cell that stores one bit of information is shown below.

  Read/$\overline{\text{Write}}$ = 0, select = 1, input data to S-R latch

  Read/$\overline{\text{Write}}$ = 1, select = 1, output data from S-R latch



SR latch with NOR gates