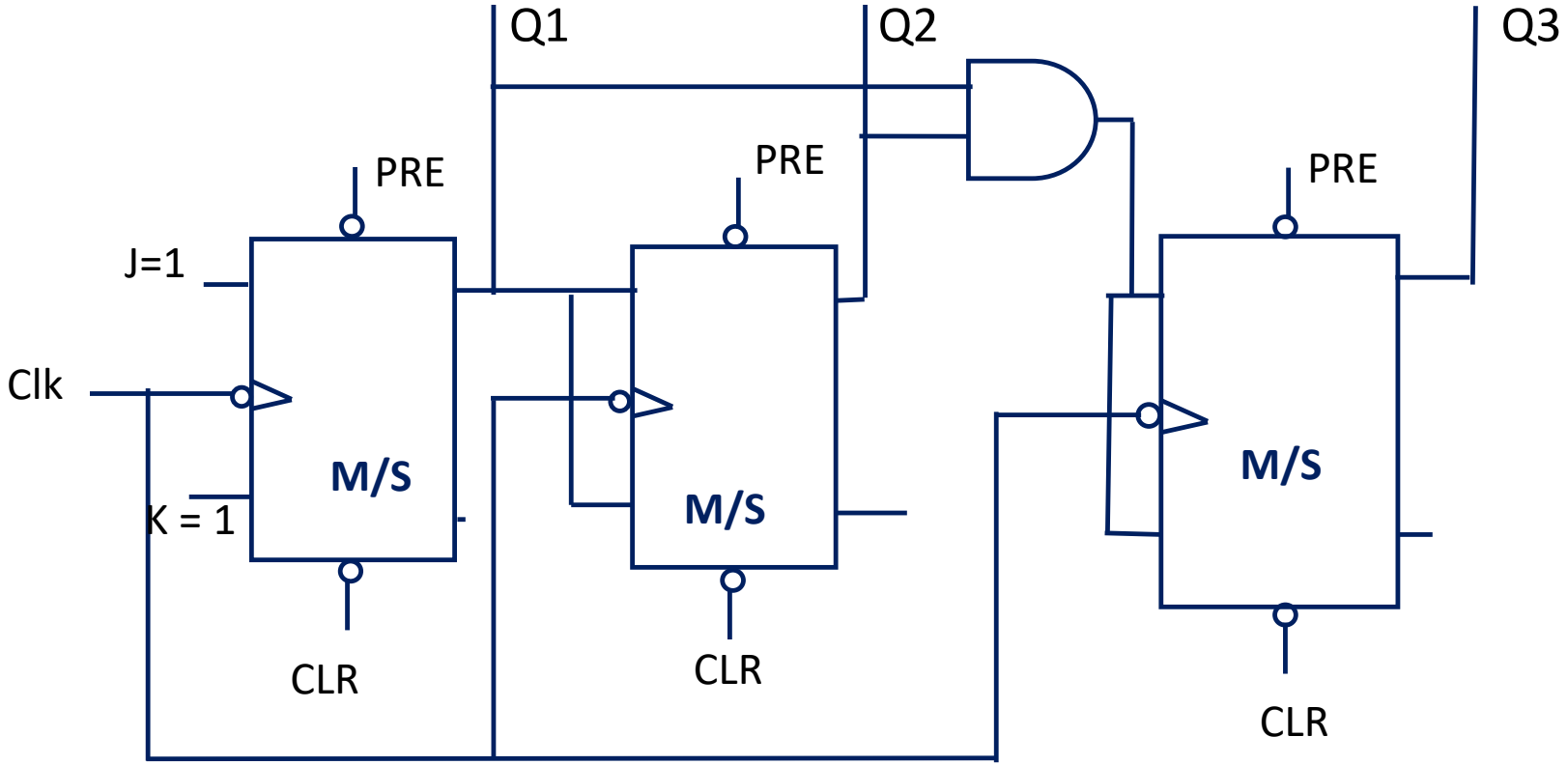
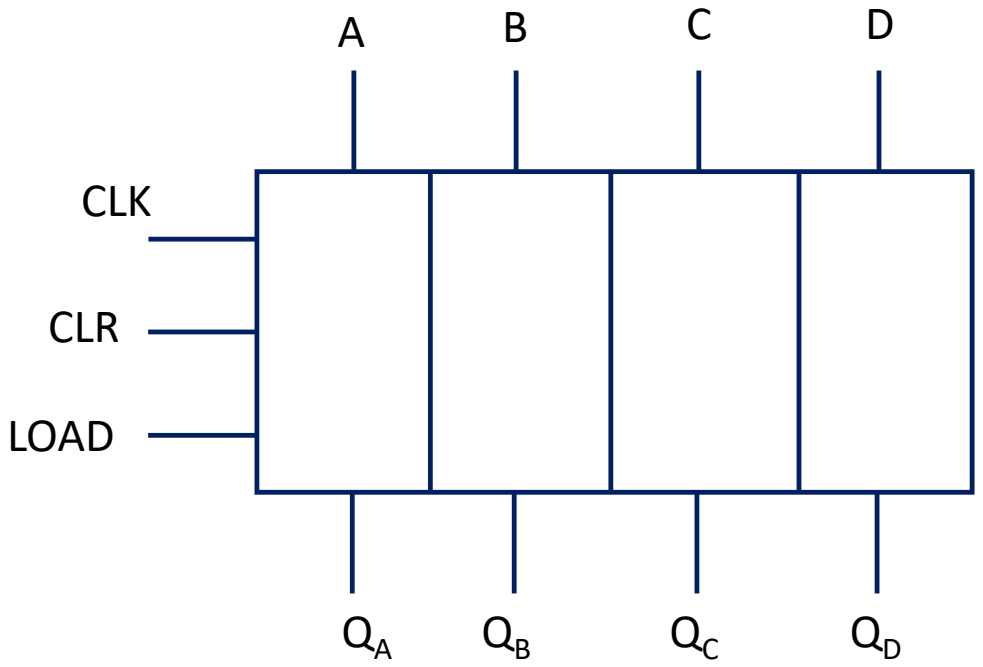
Parallel or Synchronous Counter

Q3	Q2	Q1
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1



Register

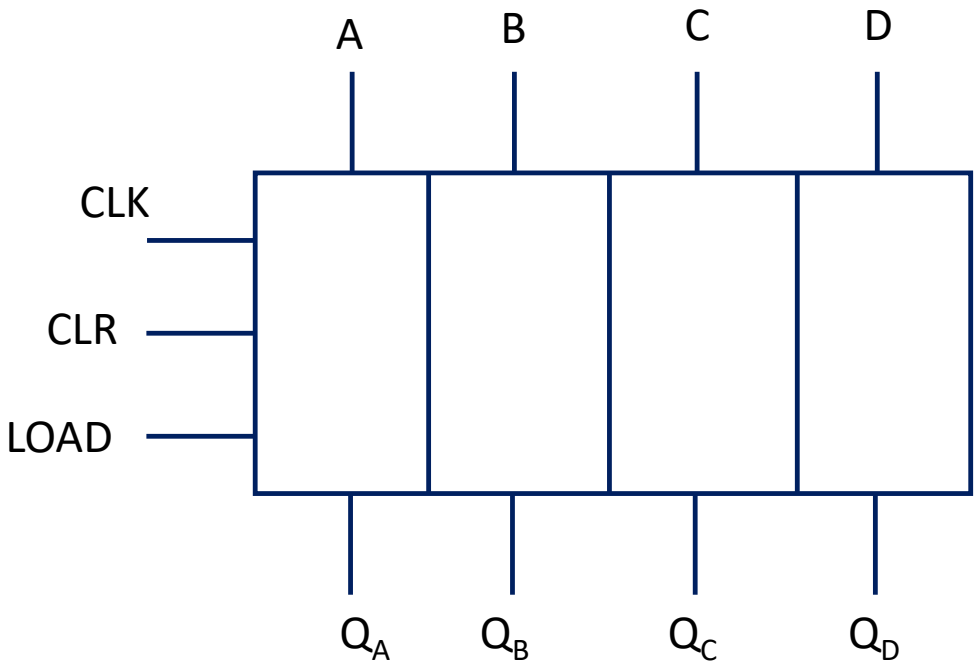
4-bit Register



- Parallel or Synchronous load
- Asynchronous load

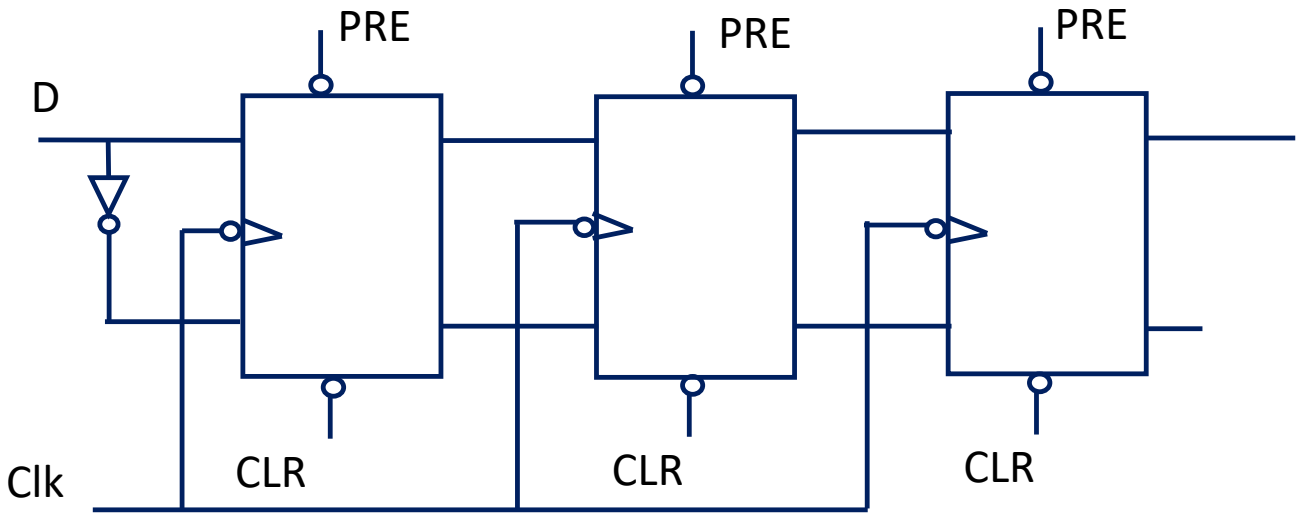
Shift Register

- In digital system, sometimes data may be required to store temporarily or may be required to move left or right one or more bit positions.
- Shift register is used to store or move data.
- Data can be entered in sequential for i.e. serial form or in parallel form.
- Shift registers can be converted into special counters called as Ring Counters.



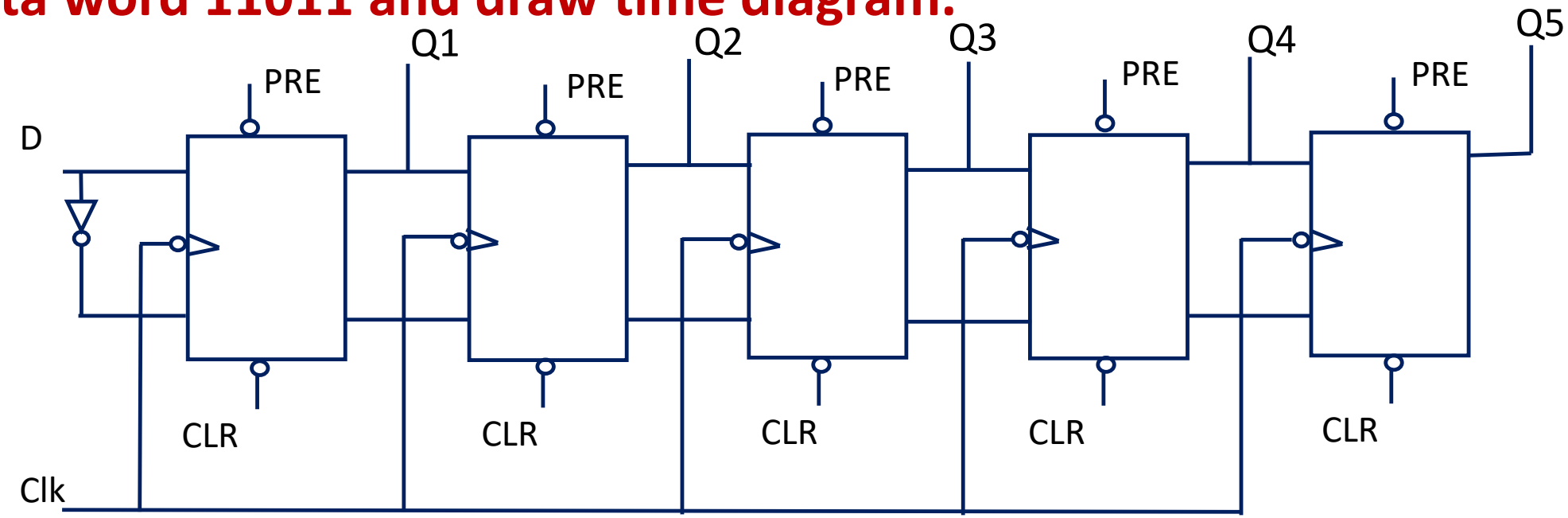
- Serial in Serial out
- Serial in parallel out
- Parallel in Serial out
- Parallel in Parallel out
- Data can be shifted to right or to the left.
- Register which can perform all the above functions called as **Universal Shift Register.**

Serial in serial out shift register



Serial in serial out shift register

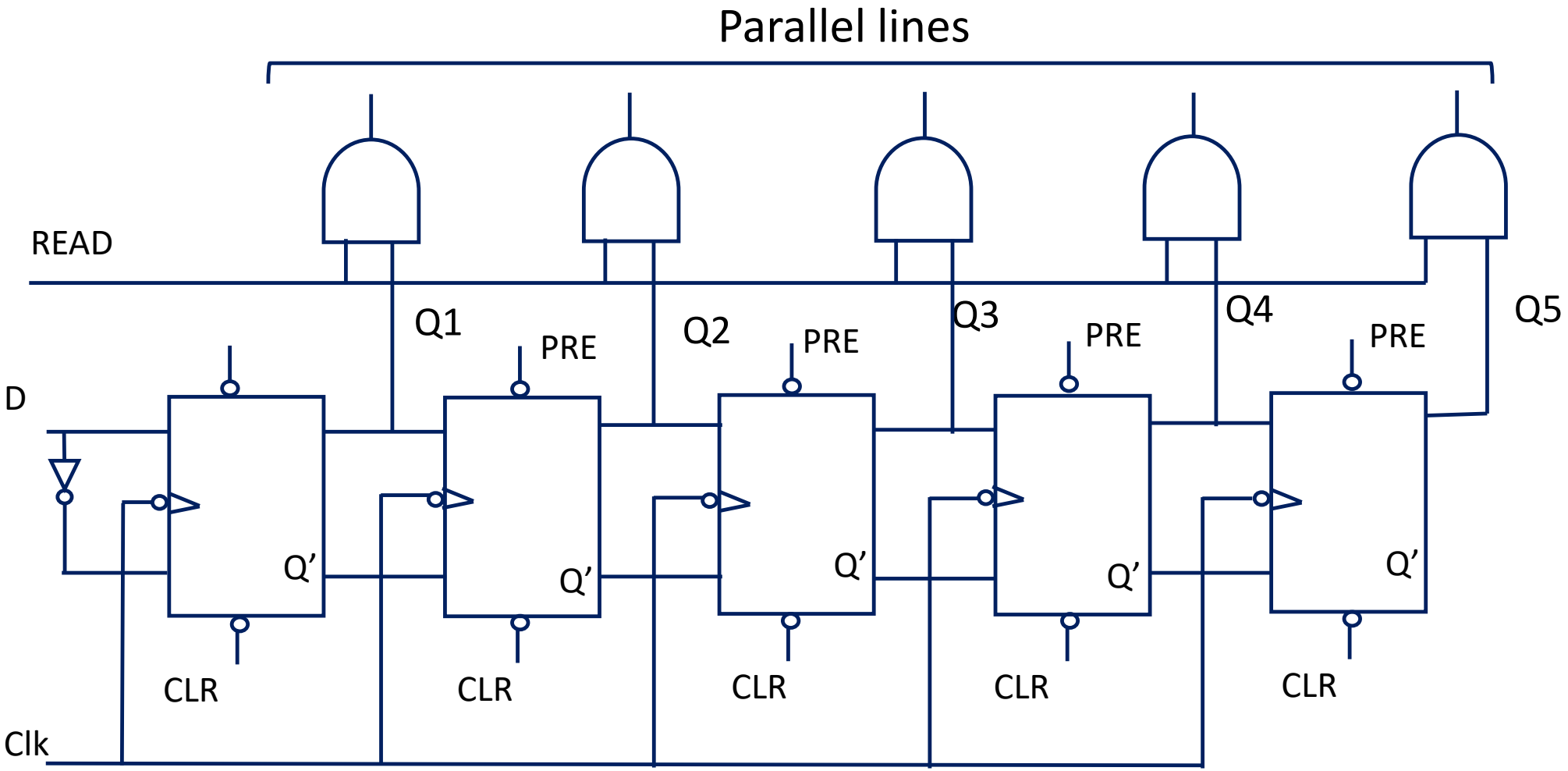
Ex. Store data word 11011 and draw time diagram.



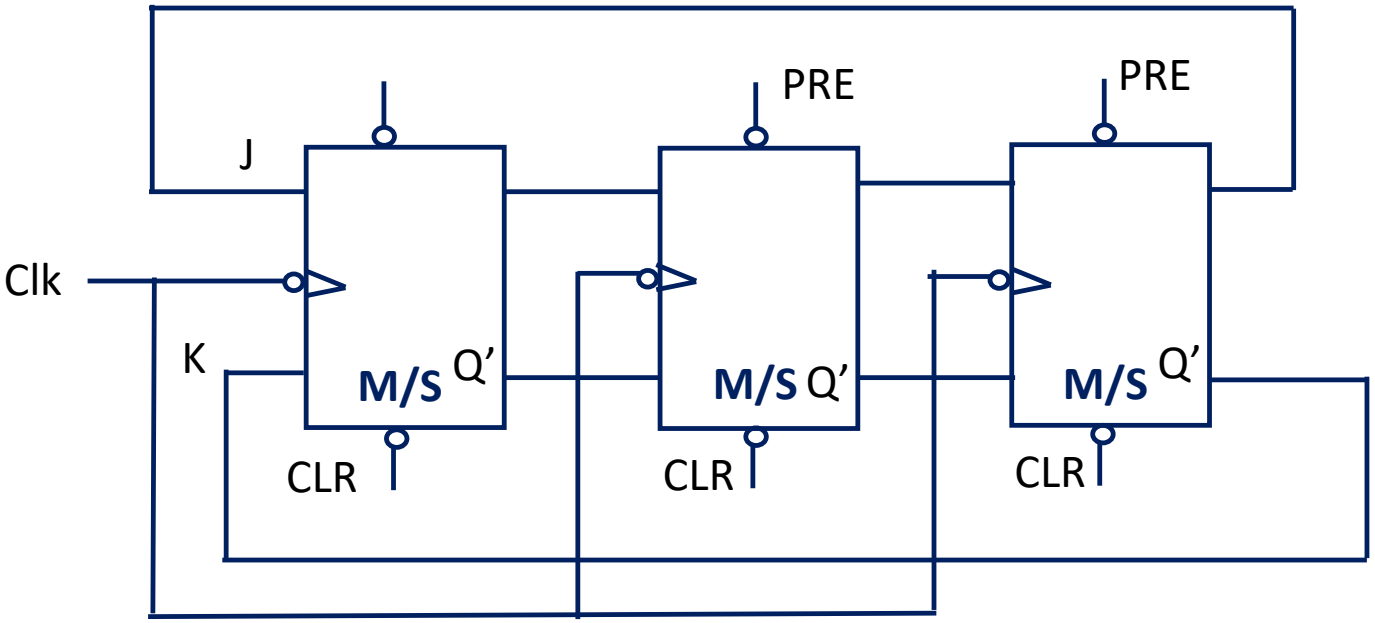
No. of Clock pulses	Q1	Q2	Q3	Q4	Q5
0	0	0	0	0	0
1	1	0	0	0	0
2	1	1	0	0	0
3	0	1	1	0	0
4	1	0	1	1	0
5	1	1	0	1	1

- First FF at left has bit 1 as LSB with positional value 2^0 while last FF has a 1 as MSB with positional value 2^4.
- Application of clock pulse beyond five loaded binary number will come out of register starting with binary number at extreme right (MSB) of FF.

Serial in parallel out shift register



Circulating shift register – Ring Counter



No. of ClK pulses	Q1	Q2	Q3
0	1	0	0
1	0	1	0
2	0	0	1
3	1	0	0

- Circuit divides clock frequency by 3 (time diagram) therefore works as MOD-3 counter.

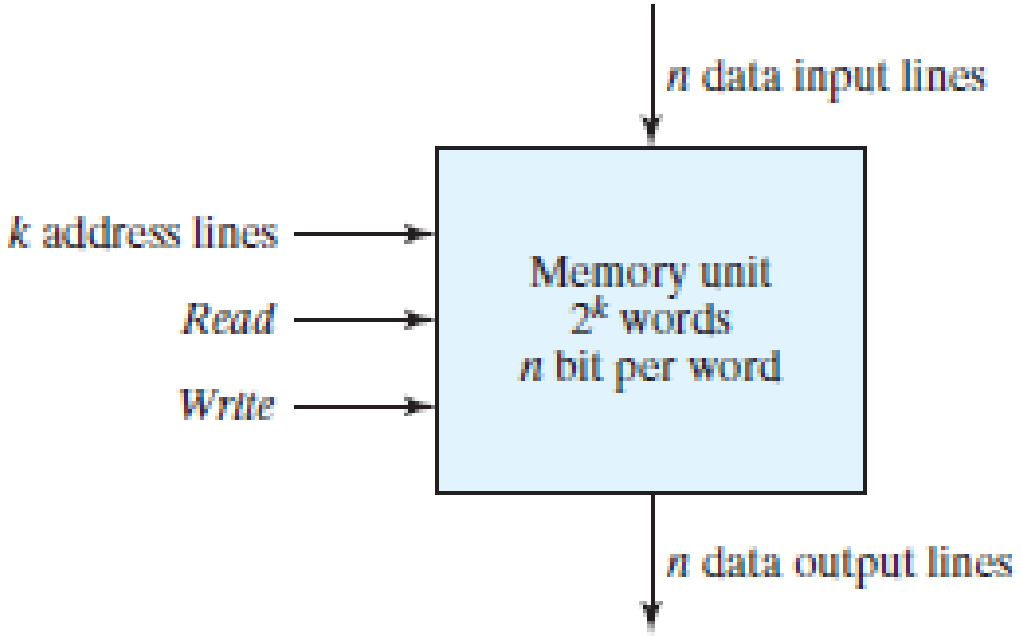
Memory

- Memory unit - A device in which binary information can be stored and retrieved when needed for processing.
- It is a collection of cells capable of storing a large quantity of binary information.
- Two types of memories used in digital systems: *Random-Access Memory* (RAM) and *Read-Only Memory* (ROM).
- RAM stores new information for later use.
- Process of storing new information into memory is referred to as a memory *write* operation.
- Process of transferring stored information out of memory is referred to as a memory *read* operation.
- RAM can perform both write and read operations.
- ROM can perform only *read* operation. i.e. suitable binary information is already stored inside memory and can be retrieved or read at any time. However, information cannot be altered by writing.

Random-Access Memory

- A memory unit is a collection of storage cells, along with circuits needed to transfer information into and out of a device.
- Architecture of memory is such that information can be selectively retrieved from any of its internal locations.
- Time taken by memory to transfer information to or from any desired random location is always the same—hence called *random-access memory,* abbreviated RAM.
- A memory unit stores binary information in groups of bits called *words.*
- A memory word is a group of 1's and 0's and may represent a number, an instruction, one or more alphanumeric characters, or any other binary-coded information.
- A group of 8 bits is called a *byte*. Most computer memories use words that are multiples of 8 bits in length. A 16-bit word contains two bytes, and a 32-bit word is made up of four bytes.
- Capacity of memory unit is the total number of bytes that unit can store.

Random-Access Memory



- *n* data input lines provide information to be stored in memory, and *n* data output lines supply information coming out of memory.
- *k* address lines specify particular word chosen among many available.
- Two control inputs specify direction of transfer
- desired: *Write* input causes binary data to be transferred into the memory, and *Read* input causes binary data to be transferred out of memory.

Random-Access Memory

- Memory unit is specified by number of words it contains and number of bits in each word.
- The address lines select one particular word.
- 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.
- Selection of a specific word inside memory is done by applying k -bit address to address lines.
- An internal decoder accepts this address and opens the paths needed to select word specified.
- Memories vary greatly in size and may range from 1,024 words, requiring an address of 10 bits, to 2^{32} words, requiring 32 address bits.
- number of words (or bytes) in memory is referred by letters K (kilo), M (mega), and G (giga).
- K is equal to 2^{10}, M is equal to 2^{20}, and G is equal to 2^{30}. Thus, 64K = 2^{16}, 2M = 2^{21}, and 4G = 2^{32}.

Write and Read Operations

- RAM can perform write and read operations.
- On accepting control signals, internal circuits inside memory provide desired operation.
- For transferring a new word to be stored into memory :

  1. Apply binary address of 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.

- Memory unit will take bits from input data lines and store them in word specified by address lines.
- Steps for transferring a stored word out of memory are as follows:

  1. Apply binary address of desired word to address lines.

  2. Activate the *read* input.

- Memory unit will take bits from word that has been selected by address and apply them to output data lines.